HANDBOOK FOR HIGHWAY ENGINEERS

HANDBOOK

FOR

HIGHWAY ENGINEERS

CONTAINING INFORMATION
ORDINARILY USED IN THE DESIGN AND CONSTRUCTION OF ROADS WARRANTING AN EXPENDITURE OF $5,000 TO $30,000 PER MILE

PART I. Principles of Design.
PART II. Practice of Design and Construction

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PREFACE TO SECOND EDITION

SINCE the publication of the first edition of this book four years ago, considerable progress has been made in the practice of road design and construction. To meet this advance, this handbook has been revised by bringing the material on top courses up-to-date, and by adding considerable data on tests, designs, costs, maintenance and specifications. Not only has much of the old material been revised, but new material, totaling approximately 100 pages, has been added. The criticisms and suggestions of many who have used the book in the field and office have aided the authors in this revision.

A more complete and systematic index has been prepared by Mr. Percy Waller.

The general arrangement of the book remains untouched.

W. G. H.
E. A. B.

ROCHESTER, N.Y., May, 1916.

PREFACE TO FIRST EDITION

THE purpose of this book is to collect, in a compact and convenient form, information ordinarily required in the field and office practice of road design and construction.

The book is designed to meet the requirements of both experienced and inexperienced road men. The material on the relative importance of the different parts of the design, and the possibilities of economy, without impairing the efficiency of the road, are primarily for the inexperienced engineer. The collection of cost data and the tables will be useful to any one engaged in road work.

As it is difficult to avoid clerical errors and mistakes in proofreading in first editions, we shall appreciate the coöperation of readers in calling our attention to any errors.

W. G. H.
E. A. B.

ROCHESTER, N.Y., April, 1912.

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HANDBOOK FOR HIGHWAY ENGINEERS

PART I. THEORY OF DESIGN

INTRODUCTORY

The necessity for the permanent improvement of the main country roads has been so well recognized by all the States that the work promises in a few years to equal in magnitude that of Railroad, Canal, and River transportation.

Highway construction has increased so rapidly that there are not enough experienced engineers to handle it. Most of the departments have been forced to use untrained men and have tried to make their plans "fool-proof" by standardizing the designs in detail. Road work is peculiarly unfitted for such treatment, as an appropriate and economical design often calls for changes every 100 feet and too much Standardization has resulted in a waste of money and unsatisfactory plans.

The general public still believes that the work requires only common-sense and that the money spent on engineering is wasted; even in the Road Departments, many of the men take this view, but it is a relic of the old "hit or miss" style of town-road construction. There is no doubt that money judiciously spent in engineering is justified by the resultant saving in total cost; there is also no doubt that much of the money spent in so-called engineering is absolutely wasted. In order to handle satisfactorily the work already in sight, we must have a larger force of technically trained roadmen, who realize the importance of the problem as an ENGINEERING PROBLEM, and who understand that a good design depends on them and not on a mechanical use of Standards. As soon as such a force is developed we can do justice to the roads.

GENERAL

Highways are improved to reduce the cost of hauling and to increase the safety and ease of light traffic. The parts of the design are more or less important in proportion to their necessity for the fulfilment of these purposes, and may be ranked as follows:

1. Selection of Roads
2. Grades and Alignment
3. Cross Sections
4. Drainage
5. Foundations
6. Top Courses
7. Minor Details

The Selection of Roads to improve is a matter of broad policy, it becomes an engineering question only when a number of roads

serve the same district, in which case the considerations of grade and economy govern.

Grades, Alignment, and Section are the most permanent features of an improvement. The ruling grade largely controls the maximum load that can be hauled; section and grade combined determine the convenience of the road and the economy of earthwork, while alignment and section affect the safety and are also important factors in the appearance of the highway. For these reasons these three points can be ranked as equal and first in importance.

Drainage, Foundation Stone, and the Top Course keep the section intact and firm under heavy traffic. The bearing power of the subgrade and shoulders is increased by the surface and subsurface drainage; the concentrated wheel loads of heavily loaded vehicles are spread over a safe area of subgrade by the foundation stone; the top course provides a surface that will withstand the abrasive action of wheels and horse-shoes, that gives a good footing and offers slight rolling resistance. At the present time the problem of the top course is more troublesome than all the other points combined, and various new styles of construction are being tried to meet the demands of both automobile and horse traffic. There is so much discussion of this one feature that it is easy to give it too much weight, and there is a tendency to economize on the more permanent and important parts of the design in order to get a higher grade top course. In the writer's opinion this is a mistake. The different types of experimental top courses will be described in detail, but as yet no definite conclusions can be drawn.

Minor Details

Minor Details include guard-rail, danger signs, guide signs, and other points affecting the safety and general appearance of the road.

The steps of the design will be taken up in the order of their importance as indicated on page 1.

ROAD BONDS

Road improvements are usually paid for by long term bonds; 50 year bonds have been very generally used. This method has been justly criticised as too long a term considering the fact that a large amount of money will be required for construction renewals before the original bonds expire. Serial bonds are a more rational method of payment.

The following tabulation is based on the average costs per mile for 200 miles of 16 ft. State roads in Western New York and shows the cost of the permanent features and temporary parts of the different forms of construction.

	Brick		Bit. Mac.		Water Mac.	
	Cost per mile	% Total Cost	Cost per mile	% Total Cost	Cost per mile	% Total Cost
* Excavation	$ 2200	9.0	$1900	15.9	$1900	18.3
* Drainage Structures	700	2.8	700	5.3	700	6.7
* Foundations and sub-base	6300	25.9	3300	27.0	3300	31.7
. Surfacing . Edging	14700	60.1	5900	47.5	4000	38.5
. Minor points	500	2.2	500	4.3	500	4.8
* Total Permanent features	9200	37.7	5900	48.2	5900	56.7
. " Temporary "	15200	62.3	6400	51.8	4500	43.3
. Probable life " "	10 to 25 years		5 to 10 years		5 to 10 years	

CHAPTER I

GRADES AND ALIGNMENT

Grades can be divided into Maximum, Minimum, and Intermediate.

Maximum or Ruling Grades

It is impossible to do justice to the question of ruling grades in the brief discussion called for by a book of this character, but the main points will be covered in the following order:

1. The relative importance of automobile and horse traffic in the selection of grades.
2. The difficulty of ascent and the ease and safety of descent.
3. The theoretical grades that fulfil certain traffic requirements, and the practical considerations that govern the selection.
4. The construction of ruling grades.

1. Under favorable conditions, gasoline and electric trucks can haul for about $0.08 to $0.10 per ton mile, traveling empty one way, while the cost of team hauling cannot be reduced much below $0.16 to $0.18. This looks like a big advantage for the trucks, but they are helpless on a poor foundation and their use for general purposes in the country is limited by bad side-roads and snow, and for produce hauling is confined to the short period of the year in which the crops are marketed. Near cities they are coming into use for milk routes, gardening produce, and the rural delivery of merchandise, but only on improved roads and only by concerns that are able to use them continuously enough to warrant the investment. Farmers must keep horses for their ordinary work and, having them, will continue to draw with teams. Mechanical trucking is bound to increase, but there seems to be no reason to believe that in the immediate future it will become more important than team hauling in rural districts and as the machines in use have sufficient power to take them up any firm surfaced grade that has heretofore been considered suitable for horse traffic, it is evident that for heavy hauling, teams still govern the selection of grade.

In Europe, mechanical tractors drawing trains of farm wagons have been used successfully. This style of hauling will probably be adopted here for limited areas, but its development into general use is a matter of conjecture. The number of wagons drawn by one machine is limited to seven or eight by the difficulties at turns and the danger of obstructing the road, rather than by the present grades. Reduced grades would lessen the fuel consumption and increase the speed slightly, but would not materially increase the train load. It would seem that such a small saving for a class of traffic that is to be developed in the future would not warrant any reduction of grade below current practice.

Light automobiles are not handicapped as much by bad roads as the heavy trucks; on fair roads their ability to cover long distances quickly makes them adapted to many uses, but they are not now

and probably never will be, as effective as horses for general use under all conditions. The least powerful of these light machines have no difficulty on firm surfaced 8% to 10% grades, which eliminates them as a factor in determining the maximum rate. From the preceding statements of the present and probable future conditions of both light and heavy traffic it is reasonable to conclude that the horse and not the machine should govern the design of the Ruling Grade.

2. Various grades on country roads have been under observation for so many years that it is safer to be guided by present practice, which is the result of such observation, than to trust too much to a theoretical discussion. The adoption of the ruling grades given in Table 1 has depended partly on the ease of maintenance as well as the traffic considerations; the maximum grades on which different top courses can be safely used, either on account of foothold for horses or the maintenance of the surface, properly come under a discussion of such courses, and will be included in chapter V.

TABLE 1

RULING GRADES IN FOREIGN COUNTRIES

	Mountainous Districts	Hilly Districts	Level Districts
Prussia	5 %	4 %	$2\frac{1}{2}$%
Hanover	4 %	$3\frac{1}{3}$%	$2\frac{1}{2}$%
Baden	8 %	6 %	5 %
Brunswick	$5\frac{1}{2}$%	4 %	3 %
Holyrod Road in England	6 %	$3\frac{1}{2}$%	—
Military Highway over the Alps	Italian side $4\frac{1}{2}$%	Swiss side 6 %	
	National Roads	Departmental Roads	Subordinate Roads
France	3%	4%	6%

RULING GRADES IN THE UNITED STATES

State	Main Roads	Side Roads	Unusual Cases
New York	5%	7 & 8%	11%
Massachusetts	5%	7%	—
Connecticut	5%	—	—
New Jersey	5%	6–7%	9%
Michigan	6%	—	—
Missouri	5–6%	—	—
Washington	5%	5%	—
Illinois	6%	—	9%

European observers claim that on a stone road, 5% is the maximum grade that can be descended safely by a trotting team without the application of brakes, and that 12% is the maximum that can be descended safely with brakes. Safe descent with brakes need not be considered, as it would result in a grade far beyond ordinary practice; safe and easy descent without brakes very evidently plays a part in the selection of the ruling grade, but is more important for light teams with a small load, traveling at a comparatively rapid rate, than for heavy hauling teams which rarely trot.

The writer knows of no records of actual maximum loads that can be drawn up different grades by an ordinary team; it is probably better to discuss this point theoretically, as any experiments would be affected by too many variable local conditions to be worth much as a basis for comparison.

A summary of Prof. I. O. Baker's discussion of maximum team loads is given below, and through his courtesy we are enabled to include a collection of tables taken from his work "Roads and Pavements."

Various trials have determined that the normal tractive power of a horse traveling three miles per hour for ten hours a day is approximately one tenth of its weight; that when hauling up a steep grade it can exert one fourth of its weight for a short time; that for a continuous exertion of one fourth, the grade should not be over 1200 feet long, and if over that, resting places must be provided every 600 to 800 feet; that in starting and for a distance of 50 to 100 feet, one half of its weight can be used; and that the net tractive power exerted by a horse on a grade equals ($\frac{1}{4}$ its weight) — (the effort required to lift itself), or approximately $W/4 - W \times$ per cent of grade expressed in hundredths, i.e. $(W/4 - 0.04W)$ for a 4% grade.

Table 2 shows the effective tractive power of a team of 1200-pound horses on different grades.

TABLE 2

	Grade	Theoretical Tractive Effort	Tractive Effort in Pounds
W = Weight of team, 2400 lbs.	Level	$\frac{1}{10}$ W	240
P = Per cent of grade in hundredths.	$2\frac{1}{2}$%	w/4 − PW	540
	4 %	w/4 − PW	504
	5 %	w/4 − PW	480
	6 %	w/4 − PW	456
	7 %	w/4 − PW	432
	8 %	w/4 − PW	408
	9 %	w/4 − PW	384
	10 %	w/4 − PW	360

This power is used in overcoming axle friction, gravity resistance, and rolling resistance.

The axle friction is small, amounting to three or four pounds per ton for American farm wagons.

Grade resistance (gravity) equals (Load x per cent of grade expressed in hundredths) and expressed in pounds per ton of load equals (2000 x P).

The rolling resistance varies for different surfaces and for each surface depends on the diameter of wheel, width of tire, speed of travel, and the presence or absence of springs on the wagon. The best diameter of wheels, best width of tires, and the use of springs as they affect the ease of hauling for both farm and road use are problems for the wagon manufacturers.

Morin, a French engineer, concluded, from a series of careful experiments, that the harder the surface of the road the less effect the width of tire had on rolling resistance. We are dealing with comparatively hard surfacing only and with small differences in wheel diameters and can disregard these factors. As a matter of interest Tables 3, 4, and 5 are included to show the results of experiments on different soils and roads.

The question of wide tires is necessary to road engineers only as it affects the distribution of wheel loads over a safe area and will be taken up under Foundations.

TABLE 3.—EFFECT OF WIDTH OF TIRE UPON TRACTIVE POWER[1]
RESISTANCES IN POUNDS PER TON

Ref. No.	Description of the Road Surface	Diameters of the Front & Rear Wheels respectively									
		3′–6″ & 3′–10″		3′–6″ & 3′–10″		3′–8″ & 4′–6″		3′–6″ & 3′–10″		3′–8″ & 4′–6″	
		Width		of		Tires					
		1½″	4″	1½″	4″	1½″	4″	1½″	3″	1½″	3″
1	Sod							283	239	189	228
2	Earth road (hard) ...		108					152	152	114	114
3	" " (muddy)		243	268	304	236	254			265	228
4	Sand " (hard)	199	162	171	164	141	168				
5	" (deep)	371	351								
6	Gravel road (good) ..			98	117	83	80			66	76
7	Wood Block (round)	51	49	61	70	35	46		54	28	38

[1] Pamphlet by Studebaker Brothers Manufacturing Company, 1892.

TABLE 4. — EFFECT OF SIZE OF WHEELS ON TRACTIVE RESISTANCE[1] POUNDS PER TON

Ref. No.	Description of Road Surface	Mean Diameter of Front & Rear Wheels		
		50″	38″	26″
1	Macadam, slightly worn, fair condition	57	61	70
2	Gravel road, sand 1″ deep, loose stones	84	90	110
3	" " upgrade 2.2%, one-half inch wet sand, frozen below	123	132	173
4	Earth road. Dry and hard	69	75	79
5	" " ½″ sticky mud, frozen below.....	101	119	139
6	Timothy & blue grass sod, dry grass cut	132	145	179
7	" " " " " wet & spongy......	173	203	281
8	Cornfield; flat culture across rows, dry	178	201	265
9	Plowed ground; not harrowed, dry & cloddy ..	252	303	374
10	Average Value of Tractive Power	130	148	186

[1] Experiments of Mr. T. I. Mairs at the Missouri Agricultural Experiment Station.

TABLE 5. — TRACTIVE RESISTANCE OF BROAD AND NARROW TIRES.[1] RESISTANCE IN POUNDS PER TON

Ref. No.	Description of Road Surface	Width of Tire $1\frac{1}{2}''$	Width of Tire $6''$	No. of Trials
1	Broken Stone, Road; hard, smooth, no dust, no loose stone	121	98	2
2	Gravel Road; hard and smooth; a few loose stones	182	134	2
3	" " " no ruts, large quantity of sand	239	157	1
4	" " new gravel, not compact, dry	330	260	1
5	" " wet, loose sand 1" to $2\frac{1}{2}''$ deep	246	254	2
6	Earth Roads. Loam, dry, loose dust 2" to 3" deep	90	106	2
7	" " " dry and hard, no dust, no ruts, nearly level	149	109	3
8	" " " stiff mud, drying on top, spongy below	497	307	1
9	" " " mud $2\frac{1}{2}''$ deep, firm below	251	325	1
10	" " Clay, sloppy mud, 3" to 4" deep, hard below	286	406	1
11	" " " dry on top but spongy below	472	422	2
12	" " " dry on top but spongy below	618	464	5
13	" " " stiff deep mud	825	551	1
14	Mowing Land. Timothy sod, dry, firm, and smooth	317	229	1
15	" " " " moist	421	305	1
16	" " " " soft and spongy	569	327	1
17	Pasture " Blue grass sod, dry, firm, and smooth	218	156	2
18	" " " " " soft	420	273	2
19	" " " " " soft	578	436	1
20	Stubble " Corn stubble, no weeds, dry enough to plow	631	418	2
21	" " " " some weeds, dry enough to plow	423	362	1
22	" " " " in Autumn, dry and firm	404	256	2
23	Plowed " Freshly plowed, not harrowed, surface rough	510	283	1
24	" " " " harrowed, smooth, compact	466	323	1

[1] Missouri Agricultural Experiment Station Bulletin No. 39.

Table 6 gives the average rolling resistance in pounds per ton of load on different pavements for the ordinary farm wagon driven at ordinary speeds.

TABLE 6[1]

Kind of Pavement	Rolling Resistance in Lbs. per Ton of Load
Asphalt	30 to 70
Brick	15 to 40
Cobble Stones	50 to 100
Earth Roads	50 to 200
Gravel Roads	50 to 100
Macadam Roads	20 to 100
Plank	30 to 50
Stone Block	30 to 80
Wood Block	30 to 50

[1] Baker's "Roads and Pavements."

For a comparative estimate we will take a value of forty pounds per ton of load, including axle friction, on Bituminous Macadam, Waterbound Macadam, and Brick Pavement, and one hundred pounds per ton for earth roads in fair condition. The resistance to the effective tractive power of the team per ton of load is therefore 40 + (2000 x P) on the improved roads, and 100 + (2000 x P) for earth roads, and the maximum load that can be drawn on any grade equals

$$\left(\frac{\text{Effective tractive power of team for that grade}}{\text{Resistance per ton of load for that grade}}\right)$$

Using the tractive powers of the team shown in Table 2, the following table is constructed.

TABLE 7

Grade	Effective Tractive Effort	Improved Roads		Earth Roads	
		Resistance in lbs. per Ton of Load	Maximum Load in Tons	Resistance	Max. Load
Level	240 lbs.	40 lbs.	6.0 tons	100 lbs.	2.4 tons
$2\frac{1}{2}\%$	540 "	90 "	6.0 "	150 "	3.6 "
4 %	504 "	120 "	4.2 "	180 "	2.8 "
5 %	480 "	140 "	3.4 "	200 "	2.4 "
6 %	456 "	160 "	2.9 "	220 "	2.1 "
7 %	432 "	180 "	2.4 "	240 "	1.8 "
8 %	408 "	200 "	2.0 "	260 "	1.6 "
9 %	384 "	220 "	1.7 "	280 "	1.4 "
10 %	360 "	240 "	1.5 "	300 "	1.2 "

NOTE. — This table is chiefly useful in comparing the effect of different grades on improved and unimproved roads, but in the writer's opinion the theoretical loads are nearly correct.

3. From Table 7 and the preceding discussion we can pick out the grades that theoretically fulfil certain traffic requirements.

I. On improved roads the same load that can be drawn up a $2\frac{1}{2}\%$ grade by the maximum exertion of a team, can be hauled on a level with normal exertion. This makes a perfectly balanced design from the standpoint of team hauling. The theoretical load is six tons.

II. 5% is the maximum grade that fulfils the condition of safe descent at a trot without brakes; this requirement is more important for light than for heavy traffic. The theoretical load for this grade is 3.4 tons.

III. The same load that can be hauled up a 7% improved grade can be drawn on a level dirt road in fair condition; a 7% grade therefore does not reduce the load of a team which must travel over an earth road for part of the distance. The theoretical load is 2.4 tons.

As a matter of fact, the actual traffic conditions, the topography of the country, and the money available, govern the selection of the grade. The theoretical advantage of a 7% grade does not really amount to much, as where the improved road has a small ruling grade, the farmers often use snatch teams to draw to the road and single teams for the balance of the distance. The adoption of 7% by many of the States depends on the topography, as will be shown later.

The average farm wagon in New York State weighs about 1350 pounds, and 3500 pounds is a large net load for such a wagon; even with larger wagons and a snatch team it is not likely that more than four tons would be drawn over dirt roads to the improved road. There is no possibility of an average team load of six tons, which means that a $2\frac{1}{2}\%$ ruling grade need not be considered except in flat country where it can be built cheaply. A 5% grade has been found from experience to be satisfactory for most localities, as $3\frac{1}{2}$ to 4 tons can be hauled, teams can descend it easily, and the cost of construction is usually not too great.

In the improvement of any highway or system of highways, the amount of money that the community is willing to provide is often insufficient to build a road that the conditions demand. This limits the engineer to the best design he can make for the amount available. In such a case the grade should be consistent even if it cannot be reduced to a rate that would meet the traffic requirements, and should be designed primarily for heavy hauling. As the advantages of these roads are demonstrated, there is less difficulty in getting sufficient money for a good design.

Take for example a road between two shipping points. It is first necessary to determine the portion tributary to each shipping center, and then the natural grade of all the hills on each portion, in order to decide what consistent ruling grade can be adopted without excessive cost.[1] There is no object in reducing a hill from 7% to 5% at a large expenditure if nearer the terminal there is a grade that cannot be reduced below 7%. It should be borne in mind, however, that the nearer you approach the center, the more traffic the road will have, and if the hills are naturally flatter the ruling grade should be reduced. The direction of heavy traffic on each hill should be determined and

[1] For an example, see page 151, chapter VIII.

considered. In the writer's opinion there are few cases where grades less than 5% are required, and in hilly country 7% is satisfactory and a great improvement over previous conditions.

Grades as high as 11% have been constructed in New York and grades as high as 9% in New Jersey and Illinois, but the general opinion of the Departments under which these grades were built is that they would not again use such a high rate except in villages where any material change in street elevation would damage valuable properties. Outside of corporations it is bad practice to use grades greater than 7%, for if any road is of sufficient importance to warrant an improvement of the class discussed in this book, it is certainly of sufficient importance to warrant a reduction in grade to a reasonable rate.

4. CONSTRUCTION OF MAXIMUM GRADES

Natural grades are reduced to the required rate by cut and fill, by new locations around hills, or by new locations giving additional length for the same rise. The cheapest method is usually adopted, but sometimes where cut and fill would be the most economical in the first cost, the danger of drifting snow in cuts or the damage to abutting property from deep cuts or high fills results in the selection of the more expensive construction. A large reduction of grade on a long hill necessarily requires a new location.

MINIMUM GRADES

Most road books claim that level grades should not be used because of the liability of water standing in ruts and that a certain minimum grade should be adopted that would insure their longitudinal drainage. Baker states in his "Roads and Pavements" that for macadam roads, English engineers use a minimum grade of 1.5%, French engineers 0.8%, and that American practice favors 0.5%. Let us see what this means:

for a 1.5%	grade	the	fall	would	be	1/5	inch	per	foot
" " 0.8%	"	"	"	"	"	1/10	"	"	"
" " 0.5%	"	"	"	"	"	1/16	"	"	"

The flattest crown that is ordinarily used even on bituminous macadam is $\frac{1}{2}''$ per foot or $2\frac{1}{2}$ times as much as the greatest longitudinal fall in the above list.[1] For long ruts a longitudinal grade is of course effective, but the patrol system of maintenance is supposed to prevent their formation and for short small depressions the crown slope must furnish the drainage. The writer believes that there should be no hesitation in using a level grade; on such stretches the crown can be increased slightly to insure transverse drainage and the ditches given a minimum longitudinal fall of 0.2′ to 0.5′ per 100′, depending on the soil.

INTERMEDIATE GRADES

The selection of the intermediate grades affords the greatest chance for economy on earth work. A grade so established that the cut in

[1] See footnote, page 19.

every cross-section would just make the fill at that point, would result in the least possible excavation. This condition is never realized, but the nearer it is approximated, the nearer we get to the most economical grading design. (See chapter on Office Practice, page 221.)

It may be noted at this point that economy of grading should never govern the profile or cross-section where there is any good reason of convenience, safety, or appearance for placing the road at a certain elevation or giving it a certain shape.

In determining the profile the controlling features should first be noted; these are high-water level of streams, elevations of existing bridges, railroad crossings, all points where deep cuts or high fills would damage the approaches to valuable property; connections with other highways, portions of the road that have been previously macadamized, and in villages the elevation that will give a convenient section and a finished appearance. The adopted grade must satisfy these conditions. However, on the greater part of an ordinary road, the grade can be placed at any desired elevation, and it is on these stretches that the saving in earthwork is effected. To get an economical design, a rolling grade can be used if necessary; long straight grades are not required, a mistake easily made by engineers trained in railroad work. Short grades are not objectionable, and a reverse vertical curve rides easily if well built. It appears that there is too much tendency to cut the top of every knoll and fill each hollow, for it seems a waste of money to reduce a 4% to a 3.5% or a 3.5% to a 3% grade where the ruling grade is 5%. There should be no hesitation in spending all the money that can be obtained to reduce the ruling grade to a reasonable rate, but it is good policy to economize on all grades less than the maximum.

In conclusion, it should be stated that probably the most common error in the laying of a profile consists in making the excavation and embankment balance with short hauls, *regardless* of more important considerations, and in this connection it cannot be stated too strongly that the grade must satisfy the controlling points; that any resulting excess of material must be overhauled or wasted and any shortage borrowed; that the economies must be effected on the unimportant stretches of road, and that by the use of short and rolling grades the excavation can be reduced and a good profile obtained.

Table 8 gives the excavation per mile on State roads in different localities and indicates the variation in amount that is required to get a first-class improvement.

TABLE 8

PART 1. — COMPILED FROM THE 1908 AND 1909 REPORTS OF THE NEW JERSEY HIGHWAY COMMISSION.

Name of Road	Length in Miles	Maximum Original Grade	Max. Improved Grade	Excavation in cu. yds. per Mile
May's Landing	14.0	7.0%	3.2%	2,220
Rivervale	5.0	8.5%	5.0%	4,680
Westwood	1.2	5.2%	4.5%	2,500
Franklin Turnpike	1.6	8.0%	2.8%	8,200
Summit	1.9	13.0%	6.5%	5,200
Lamberton	3.9	2.8%	2.8%	540
Westfield	3.1	4.5%	2.9%	6,500
Blue Anchor	2.3	2.5%	2.0%	3,200
Malaga	5.7	4.2%	2.0%	1,700
Whitehouse	6.5	12.5%	5.0%	4,100
English Creek	6.7	6.0%	3.9%	2,000
Paterson Plank Road	2.3	Level	Level	(Emb.) 50,000
Yesler Way	2.7	12.0%	6.5%	5,700
Camden	2.4	6.7%	4.0%	5,200
Evesham	2.4	6.4%	3.7%	3,500
Schellenger's Landing	2.1	3.4%	1.1%	5,000
Goshen	2.6	3.4%	1.4%	4,500
Tuckahoe	4.3	4.1%	1.6%	8,100
Hopewell	2.0	7.6%	5.0%	3,800

TABLE 8

PART 2. — COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans for 1911

Name of Road	Character of Country	Maximum Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
Pittsford — North Henrietta	Rolling	5.0%	24′	2500
Indian Falls — Corfu	Flat	2.6%	24′	2800
Pembroke — East Pembroke	Hilly	5.0%	32′	3600
Livonia — Ontario County Line	Hilly	8.0%	32′	5500
Livonia — Lakeville	Hilly	8.0%	32′	4500
Avon — Lima	Hilly	8.0%	32′	3300
Sea Breeze — Nine Mile Point	Hilly	8.0%	26′	6600
Bliss — Smith's Corners	Rolling	5.5%	26′	3400
Wales Center — Wales	Hilly	8.0%	28′	5700
Scottsville — Mumford	Rolling	5.0%	32′	3400
Ridge — Rochester — Sea Breeze	50% Flat 50% Hilly	1.5% 5.0%	32′ & 44′	3350
Medina — Alabama	Rolling	5.0%	28′–32′	2800
Pavilion — Batavia	Hilly	10.0%	22′–30′	2950
Parma Corners — Spencerport — North Chili	Flat	6.0%	32′	2320

TABLE 8. *Continued*

COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans for 1910

Name of Road	Character of Country	Maximum Improved Grade	Width of Section between Ditches	Exc. in Cu. Yds. per mi.
Lake Part 2 & Sweden 4th Sect.	Flat	3.8%	32′	2560
Warsaw — Pavilion	"	5.0%	28′–32′	3900
East Henrietta — Rochester	Rolling	3.8%	32′	2300
Olean — Hinsdale	Flat	2.6%	28′–32′	4000
Leroy — Caledonia (1.5 miles)	Rolling	5.0%	32′–40′	1950
Shawnee — Cambria	60% Flat 40% Hilly	2.2% 7.0%	28′–32′	3150
Roberts Road	Rolling	3.1%	32′	3230
Sanborn — Pekin	Flat	2.4% One hill 5.0%	32′	2800
Oak Orchard, Part 2	Rolling	4.4%	30′–32′	2300
Levant — Poland Center	Hilly	5.0%	28′–32′	4000
Dansville — Mt. Morris, II	"	4.1%	24′	6200
Castile Center — Perry Center	Flat	3.6%	30′	2820
Lake Shore — Lackawanna City	"	0.7%	28′–32′	2120
Eighteen Mile Creek	Hilly	7.0%	28′–32′	6100
Albion Street — Holley	Rolling	3.7%	32′	3440
Pembroke — East Pembroke	"	5.0%	32′	3800

TABLE 8. *Continued*

COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans for 1908 and 1909 (Selected Roads)

Name of Road	Character of Country	Max. Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
Hamburg — Springville Sect. I . .	Rolling	6.0%	30′	1920
" " " II . .	Hilly	7.0%	30′	3100
Collins — Mortons Corners	"	7.0%	32′	2250
Clarence Center	Flat	2.5%	28′	2200
Orchard Park — Griffin's Mills . .	Hilly	8.0%	28′	2000
County Line	Flat	5.0%	28′–32′	2100
Geneseo — Avon	Hilly	5.3%	32′	2200
Geneseo — Mt. Morris	"	6.0%	32′	3460
Alden — Town Line	Flat	6.0%	22′–28′	1960
Pittsford — Mendon	Hilly	6.0%	32′	3000
Pittsford — Despatch	"	5.0%	24′	3600
Clover Street Section I	"	8.0%	28′	2550
" " " II	Rolling	4.5%	32′	3000
Rich's Dugway	Hilly	7.2%	20′–28′	5000
Left Fork — German Church . . .	Rolling	6.2%	28′	2000
Goodrich Road	60% Flat 40% Rolling	5.0% 6.0%	26′–32′	3100
Hamburg — North Collins	Hilly	9.0%	22′–32′	4200
Lawton — Gowanda	"	7.5%	32′	5300
Chili	Rolling	5.0%	28′	2800
Brooks Avenue	Flat	4.6%	24′–30′	2240
Lyell Avenue	"	2.2%	26′–30′	2400
Barnard's Crossing	"	4.4%	22′	2174

TABLE 8. *Continued*

COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans from 1898 to 1907. (Selected Roads)

Name of Road	Character of Country	Max. Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
East Avenue	Rolling	5.0%	22′	8160
Pittsford	"	5.0%	22′	5840
Fairport	"	5.5%	20′–22′	6580
Ridge Road	"	3.3%	26′	2150
Buffalo Road	Flat	2.0%	22′–25′	1700
White's Corners Plank Road	"	3.5%	22′	4600
Orchard Park	"	3.9%	20′	4200
Transit, Sections I & II	"	4.6%	22′	2100
Hudson Avenue Road	Rolling	3.1%	22′	7100
West Henrietta	Flat	5.5%	22′	3400
Scottsville, Section I	"	4.0%	22′	2000
" " II	Rolling	5.0%	22′	2100
Monroe Avenue	Flat	4.5%	22′–24′	1850

An examination of the 1909 report of the New York State Highway Commission shows that the largest excavation per mile on roads built by the State from 1898 to 1908 was as follows:

Delaware Turnpike Road	. . . 1.04 miles	. . . 16800	c.y. per mile
" " "	. . . 6.5 "	. . . 6800	" " "
North Creek-County Line	4.12 "	. . . 10300	" " "
Highland Lake-Tompkins Cove	5.88 "	. . . 10100	" " "

and the least excavation as follows:

Main Street, Section II	986	" " "
Babylon-Bay Shore	735	" " "

TABLE 8

PART 3. — COMPILED FROM THE REPORTS OF THE MASSACHUSETTS STATE HIGHWAY COMMISSION. 1896

Name of Road	Length in Miles	Maximum Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
Andover	0.6	4.9 %	24	6000
Brewster	1.0	3.36%	21′	2607
Dalton	1.5	6.0 %	30′	1920
Gloucester	1.6	5.0 %	21′	3200
Granby	0.63	2.7 %	21′	5300
Great Barrington	1.0	2.6 %	21′–24′	2300
Hadley	1.49	4.0 %	21′	8930
Munson	0.93	2.95%	21′	3000
Norfolk	1.2	5.3 %	21′	3350
North Hampton	0.56	1.25%	26′	4300
Pittsfield	1.0	4.25%	21′	4700
Tisbury	1.93	4.40%	21′	7540
Westport	3.0	1.7 %	24′	1500
Wrentham	1.62	4.0 %	21′	3700
Walpole	1.61	6.0 %	21′	5600
Duxbury	1.05	3.8 %	21′	3800
Fairhaven	1.45	4.0 %	21′	1200
Fitchburg	0.97	6.0 %	21′	4500
Goshen[1]	1.91	5.0 %	21′	9700
Marion	1.48	5.0 %	21′	1500
Mattapoisett	1.16	4.25%	21′	1810
Lee	1.5	5.16%	—	3500
Leicester	2.0	5.0 %	—	3800

This table is compiled to show the amounts of excavation that the Highway Departments of Massachusetts, New York, and New Jersey have been willing to use in getting various maximum grades. It can be readily seen that it is impossible to generalize as to how much excavation will be required. In the chapter on "Sections" some examples will be given of roads for which two designs were made, using different widths of section and different kinds of profile, to show the saving that can be effected by a careful selection of the section and the use of a rolling grade.

[1] Original maximum grade 12% — new location used; as difficult a road as there is in the State to obtain a 5% grade.

ALIGNMENT

Sharp curves on steep grades or at the foot of such grades are not safe; good practice calls for a minimum radius of 300 to 400 feet for these cases. Right angle turns even on level stretches are inconvenient and often dangerous. New York State has adopted a radius of 200 feet as a minimum, wherever possible, acquiring new right-of-way when necessary, and it is very evident that the increased comfort has pleased the traveling public.

On comparatively straight stretches the position of the center-line should be shifted to keep on the old roadbed as much as possible and yet give a pleasing appearance; this is done to utilize the hard foundation of the present traveled way for the subgrade of the proposed metaling.

Sight Distances. — In designing a side hill road, in rough country, the alignment and width of shoulder often depends upon what we may call "a safe sight distance"; this means that the driver of a machine, traveling at ordinary touring speed of 20 to 30 miles per hour, must be able to see far enough ahead to turn out and pass an approaching car without the application of brakes. In attempting to reach a conclusion as to what is a "safe sight distance" we have written to automobile clubs throughout the country and find that, in the main, they agree on from 200 to 300 feet for speeds of 20 to 25 miles per hour.

Mr. George C. Diehl, Chairman of the Good Roads Board, A.A.A. and County Engineer of Erie County, N.Y., gave us the following information for emergency stops and passing without slowing up:

"The tests that we have conducted show that a car going at the rate of 20 miles per hour can be stopped at 40′ and one going at 40 miles per hour can be stopped at 140 feet with the emergency brake. For passing a rig going in an opposite direction this distance would not be necessary."

Mr. Diehl's figures are considerably less than the distances given in the other answers. A minimum sight distance of 250 to 300 feet is the practice of Division No. 5, New York State Department of Highways.

In the chapter on Office Practice, page 208, tables are given showing the "Sight Distance" for different curves in "cut."

Railway Grade Crossing Elimination

Grade crossings are being eliminated as rapidly as possible, as they are a source of great danger. The overhead clearance and width of roadway in subways are given in chapter IX.

CHAPTER II

SECTIONS

SECTIONS may be considered from the standpoints of safety, convenience, and economy.

For safety, a rig should be able to travel on any part of the road from ditch to ditch without overturning; for convenience, the width of section ordinarily used must have enough pitch to drain the surface water into the ditches but not enough to give an uncomfortable tilt to a vehicle; for economy, the section must be flexible in order to conform to local conditions.

The first questions are naturally: What is a safe slope? What is a comfortable driving slope? What pitch is required to drain different surfaces? What is the commonly used width, and what the maximum width of the traveled way?

All of these points except the last two have been pretty well determined, and, while some engineers disagree with current practice, the writer believes from his experience and a study of the various State sections that the following premises can be safely adopted:

That 3″ to 1′ or 1 on 4 is the maximum safe slope.

That 1″ to 1′ is the maximum agreeable driving slope.

That 1″ to 1′ is the minimum slope at which an earth shoulder will shed water, without too much maintenance.

That $\frac{5}{8}$″ to 1′ is a satisfactory crown for a waterbound macadam road in order to maintain it satisfactorily, allowing for the flattening that occurs under traffic.

That $\frac{1}{2}$″ to 1′ is a satisfactory crown on waterbound roads having tar or asphalt flush coats or on bituminous macadam or mineral bitumen.[1]

That $\frac{1}{4}$″ or $\frac{3}{8}$″ to 1′ is a satisfactory crown for brick pavement on country roads.

The width of roadway carrying the greater portion of the travel and the maximum width used when rigs turn out to pass are not so well established; these two points determine the most economical width of hard roadbed and the minimum convenient driving width, no part of which should have a transverse slope of more than 1″ to 1′.

Probably the best data can be obtained from the reports of the Massachusetts Highway Commission, which resulted from a careful study of these widths on 160 improved roads during the years 1896, 1897, 1898, 1899, and 1900. Table 9 gives the results on a few roads showing the form used and the variation from year to year; the footnote for Table 9 gives a summary of the observations on all the roads for the years 1896 to 1899 inclusive: this brief was prepared by

[1] New York State has adopted for their 1912 work a crown of $\frac{1}{2}$″ per foot for waterbound roads and $\frac{1}{4}$″ per foot for bituminous macadams; this is extremely flat, allowing for the effect of traffic (see Table 20, page 75).

J. Y. McClintock, County Engineer, Monroe County, N.Y., and gives a better idea of the conditions than would be conveyed by printing the original table in full.

TABLE 9. SHOWING WIDTHS OF TRAVELED WAY

Town or City	County	Width of Macadam	Maximum Width of Traveled Way				Width of Commonly Traveled Way			
			1896	1897	1898	1899	1896	1897	1898	1899
Athol	Worcester	17′	16′	16′	20′	18′	10′–12′	12′	14′	14′
Barre	Worcester	15′	—	13′	14′	14′	—	9′	7′	8′
Bedford	Middlesex	15′	—	12′	15′	15′	—	8′	10′	9′
Chicopee	Hampden	20′	—	20′	20′	20′	—	12′	12′	13′
Dalton	Berkshire	15′	20′	20′	21′	16′–21′	20′	16′	18′	12′–18′
Fitchburg (W.)	Worcester	15′	15′	14′	18′	18′	10′	10′	15′	14′
Huntington	Hampshire	15′	9′	11′	11′	12′	7′	8′	9′	8′
Lincoln	Middlesex	15′	15′	15′	15′	15′	10′	9′	10′	10′
Marshfield	Plymouth	15′	14′	12′	11′	12′	8′	9′	7′	7′
North Adams	Berkshire	15′	10′–12′	13′	14′	15′–20′	8′–10′	9′	10′	12′
Orange	Franklin	17′	16′	16′	20′	20′	10′–12′	12′	15′	15′
Taunton	Bristol	15′	20′	20′	15′	18′	10′–15′	10′	8′	7′–12′

Width of traveled way on 160 roads in Massachusetts, measured during the years 1896, 1897, 1898, and 1899, and printed in the report the Massachusetts Highway Commission for 1900.

The width of stone on these roads is given as 15′ wide on 130, 12′ wide on 3, and 10′ wide on 2. It should be remembered that the stone is put on very much thicker in the middle than at the edges.

The maximum width of traveled way as measured was as follows:

9 ft.	wide	on	2	roads	18 ft.	wide	on	23	roads
10 "	"	"	6	"	19 "	"	"	1	"
11 "	"	"	2	"	20 "	"	"	10	"
12 "	"	"	28	"	21 "	"	"	10	"
13 "	"	"	8	"	22 "	"	"	1	"
14 "	"	"	23	"	24 "	"	"	2	"
15 "	"	"	30	"	25 "	"	"	4	"
16 "	"	"	8	"	26 "	"	"	1	"
17 "	"	"	1	"	33 "	"	"	1	"

The width of commonly traveled way as measured was as follows:

7 ft.	wide	on	12	roads	14 ft.	wide	on	8	roads
8 "	"	"	17	"	15 "	"	"	13	"
9 "	"	"	25	"	16 "	"	"	2	"
10 "	"	"	32	"	18 "	"	"	4	"
11 "	"	"	10	"	20 "	"	"	2	"
12 "	"	"	30	"	22 "	"	"	1	"
13 "	"	"	3	"	25 "	"	"	1	"

The author has measured a number of the New York State improved roads and found that the width of heavy travel checked the Massachusetts results but that the maximum widths were more, averaging from 18 to 21 ft.; this probably can be explained by the

increase in automobile traffic since 1900, which, because of its higher speed, requires more room in passing.

Briefly stated, the widths subjected to hard wear on unimportant roads ranged from 8′ to 10′; on well traveled roads 10′ to 14′, and in unusual cases 14′ to 16′. The maximum widths used varied from 12′ to 14′ on the side roads, to 17′ and 18′ on the main thoroughfares, and as mentioned above have increased to 18–21′ in the last few years. From this data, it seems that the best practice at present requires a driving width for "turn out" traffic of about 22′, with a variable width of strong metaling determined by the traffic requirements and ranging from 10′ to 20′.

We have now practically developed a standard for the 22′ of driving width; the metaling that is to carry the heavy traffic has a specified crown for each variety and from the edge of the metaling to the limits of the 22′, the earth shoulder must have a slope of 1″ to 1′ or possibly $\frac{3}{4}$″ to 1′.

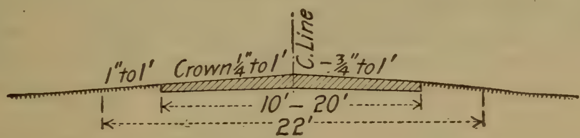


FIG. 1

The flexibility of the section depends on the portion outside of this 22′. The function of the extra width is to keep the longitudinal drainage of surface water beyond the portion used for driving. To do this we are limited to a minimum slope of 1″ to 1′ to insure transverse drainage and a maximum of 3″ to 1′ on the score of safety. It is by the good judgment of the designer in using various slopes between these limits and various widths and depths of ditches, combined with the possibilities of different grades, that the economies in earthwork are effected and at the same time the design is made appropriate to the local conditions.

Two examples are given to illustrate this point.

1. INDIAN FALLS—CORFU ROAD IN NEW YORK STATE

Length 1.85 Miles.

NO CHANGE IN PROFILE

No Change in Ratio of Cut to Fill

Original Design		Revised Design	
Width of Macadam	14′	Width of Macadam	14′
" " Section	30′	" " Section	24′
Depth of Ditch	18″	Depth of Ditch	14″
Original estimated excavation	7500 Cu. Yds.	Revised estimated excavation	5200 Cu. Yds.

This change is section alone resulted in a saving of 2300 cu. yds. excavation or at the rate of 1240 cu. yds. per mile, or in money about $600.00 per mile.

2. PITTSFORD — NORTH HENRIETTA ROAD IN NEW YORK STATE

Length 2.67 Miles

Original Design

Width of Section 30′
Depth of Ditch 18″
Ratio of cut to fill 1.35%
Maximum Grade 5.0%
Profile: — Designed with straight instead of rolling grades and tangents of 100′ between vertical curves.
Original estimated excavation 11,450 Cu. Yds.

Revised Design

Width of Section 24′
Depth of Ditch 12″–14″
Ratio of cut to fill 1.25%
Maximum Grade 5.0%
Profile: — Rolling grades and reverse vertical curves used.
Revised estimated excavation 6,620 Cu. Yds.

A saving of 4,820 cu. yds; 1,800 cu. yds. per mile, or, in money, approximately $900.00 per mile.

The revised design on this road is a good example of what can be saved by the use of a section that fits the conditions, a rolling grade, and a ratio of cut to fill that we have found from experience to be sufficient.

The author's experience has indicated that an open ditch does not have much effect on ground water; that its part in the design is to drain the surface water, thus preventing seepage into the road-bed with a resulting softening of the surface; and consequently, whenever ground water is encountered under drains should be used. Deep ditches are not only useless but dangerous, and the best practice calls for the least depth that will handle the surface water. The following section is, therefore, suitable where there is no probability of much surface water; it is the writer's idea of the minimum width section that will be satisfactory, and where it can be adopted will give the most economical grading design for light cuts and fills.

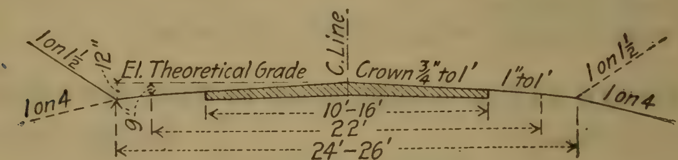
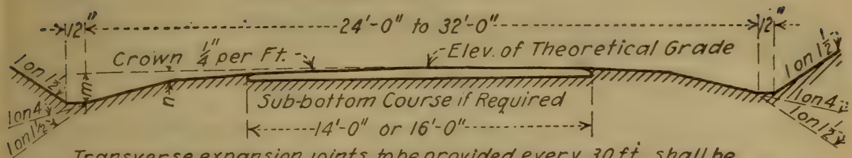


Fig. 2

New York State 1915 Standards

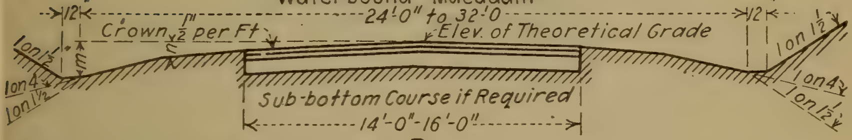
Cement Concrete



Transverse expansion joints, to be provided every 30 ft., shall be composed of a creosoted, yellow pine or tar paper strip 3/8" thick, conforming to the cross section of roadway. Each strip may be composed of two pieces of equal length, butt jointed and fastened together with approved splice piece of No. 26 Iron.

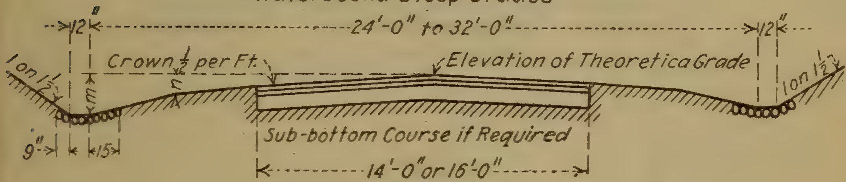
A

Waterbound Macadam



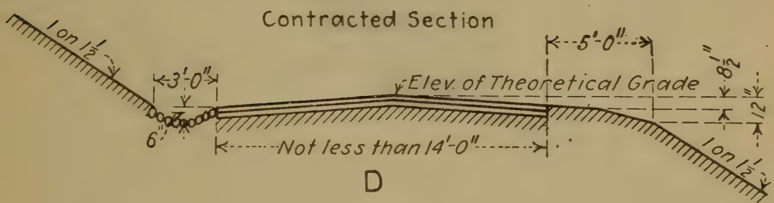
B

Waterbound Steep Grades



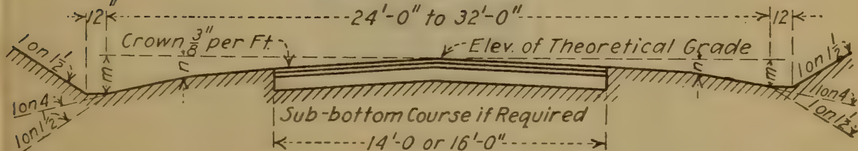
C

Contracted Section

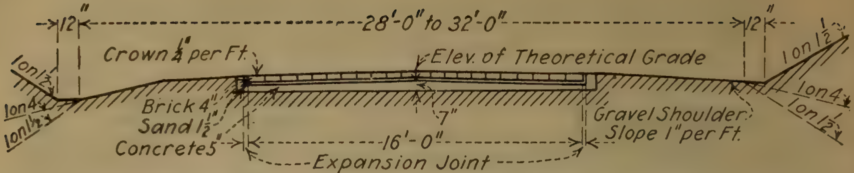


D

Bituminous Macadam

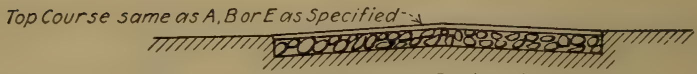


E



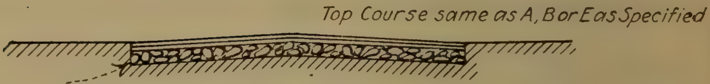
Expansion joints, if of poured type shall be 1" thick. For premoulded type they shall be ½" for 16' width, ⅝" for 20' to 24' width and ¾" for 32'-width.

Half Section F-1 Half Section F-2



Sub-base as Bottom Course

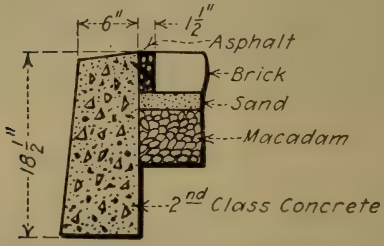
G

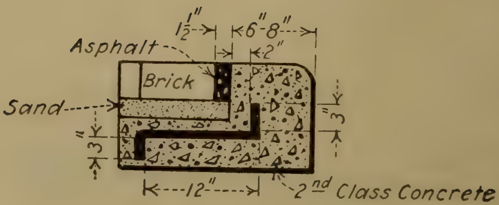


When Telford replaces Sub-base, it is made 8" thick (bottom course to have the same thickness at center and edges where Sub-base or Telford is used)

Sub-base or Telford

H





Typical Section "A"					
Shoulder	Width of Road Metal				
	14 Ft.		16 Ft.		
	"n"	"m"	"n"	"m"	
5 ft.	$4\frac{1}{4}''$	$11\frac{3}{4}''$	$4\frac{1}{2}''$	$12''$	Crown $\frac{1}{4}''$ per Ft.
6 ft.	$4\frac{3}{4}''$	$13\frac{3}{4}''$	$5''$	$14''$	
7 ft.	$5\frac{1}{4}''$	$15\frac{3}{4}''$	$5\frac{1}{2}''$	$16''$	
8 ft.	$5\frac{3}{4}''$	$17\frac{3}{4}''$	$6''$	$18''$	

Typical Section "B"					
Shoulder	Width of Macadam				
	14 Ft.		16 Ft.		
	"n"	"m"	"n"	"m"	
5 ft.	$6''$	$13\frac{1}{2}''$	$6\frac{1}{2}''$	$14''$	Crown $\frac{1}{2}''$ per Ft.
6 ft.	$6\frac{1}{2}''$	$15\frac{1}{2}''$	$7''$	$16''$	
7 ft.	$7''$	$17\frac{1}{2}''$	$7\frac{1}{2}''$	$18''$	
8 ft.	$7\frac{1}{2}''$	$19\frac{1}{2}''$	$8''$	$20''$	

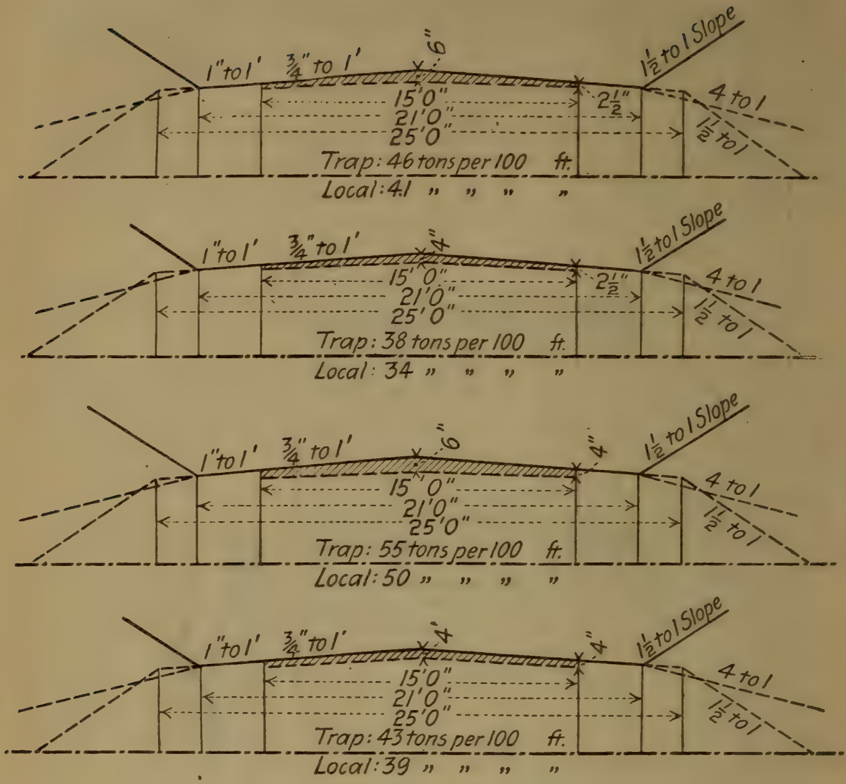
Typical Section "E"					
Shoulder	Width of Macadam				
	14 Ft.		E 16 Ft.		
	"n"	"m"	"n"	"m"	
5 ft.	$4\frac{1}{2}''$	$12''$	$4\frac{7}{8}''$	$12\frac{3}{8}''$	Crown $\frac{3}{8}''$ per Ft.
6 ft.	$4\frac{7}{8}''$	$13\frac{7}{8}''$	$5\frac{1}{4}''$	$14\frac{1}{4}''$	
7 ft.	$5\frac{1}{4}''$	$15\frac{3}{4}''$	$5\frac{5}{8}''$	$16\frac{1}{8}''$	
8 ft.	$5\frac{5}{8}''$	$17\frac{5}{8}''$	$6''$	$18''$	

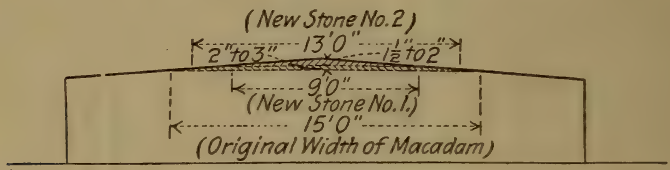
Typical Sections "F-1" and "F-2"				
Shoulder	Width of Brick 16 Ft.			
	F-1		F-2	
	"n"	"m"	"n"	
5 ft.				Crown $\frac{1}{4}''$ per Ft.
6 ft.	$4\frac{1}{4}''$	$13\frac{1}{4}''$	$8''$	
7 ft.	$4\frac{5}{8}''$	$15\frac{1}{8}''$	$9''$	
8 ft.	$5''$	$17''$	$10''$	

NOTE. "n" = difference in elevation between center of road and center of shoulder.
"m" = " " " " " " " " " ditch.
Difference in elevation given in tables are measured from theoretical grade.

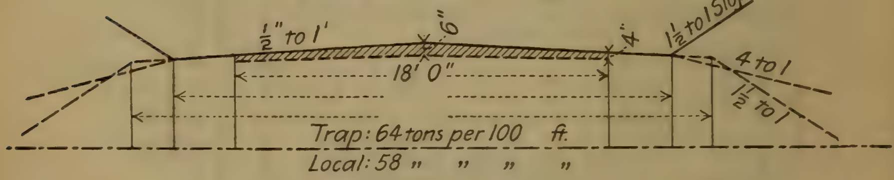
NOTE.
For widths of 20′ or less provide an expansion joint 1″ wide on each side.
" " 20′ to 30′ " " " " " $1\frac{1}{4}''$ " " " "
" " 30′ to 40′ " " " " " $1\frac{1}{2}''$ " " " "

PLATE 2

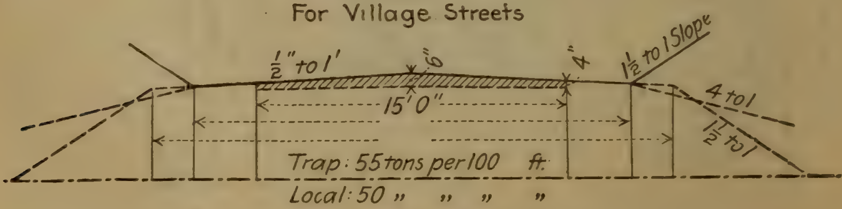




Section for Resurfacing.

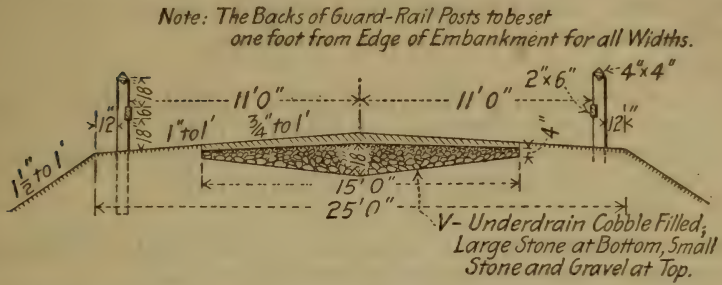


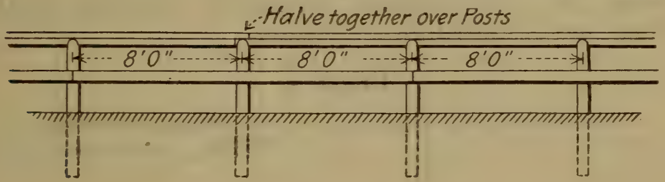
For Village Streets

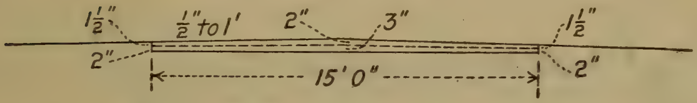


For Village Streets.

PLATE 2 — *continued*







CONDITION No. 1. — See note below.

Trap Rock — Lower course, No. 1 stone, 24 tons; screenings for binder, 4 tons. Upper course, No. 2 stone, 16 tons.

Local Stone — Lower course, No. 1 stone, 22 tons; screenings for binder, 4 tons. Upper course, No. 2 stone, 14 tons.

Total tonnage per 100′: Trap, 44; Local, 40.

CONDITION No. 2 — See note below.

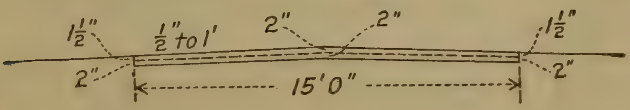
Trap Rock — Lower course, No. 1 stone, 24 tons. Upper course, No. 2 stone, 16 tons; screenings for binder, 7 tons.

Local Stone — Lower course, No. 1 stone, 22 tons. Upper course, No. 2 stone, 14 tons; screenings for binder, 7 tons.

Total tonnage per 100′: Trap, 47; Local, 43.

NOTE. — For both penetration methods — grouting or the modified Gladwell method — there should be two applications of asphaltic oil, each $\frac{3}{4}$ gal. per sq. yd. There may be also a third application of $\frac{1}{4}$ gal. per sq. yd. for a surface finish. For surface treatment there should be one application of $\frac{1}{2}$ gal. of oil per sq. yd. or two applications of $\frac{1}{4}$ gal. each per sq. yd. on the finished surface of the roadway.

PLATE 2 — *continued*



CONDITION No. 1.

Trap Rock — Lower course, No. 1 stone, 19 tons; screenings for binder, 3 tons. Upper course, No. 2 stone, 17 tons.

Local stone — Lower course, No. 1 stone, 17 tons; screenings for binder, 3 tons. Upper course, No. 2 stone, 15 tons.

Total tonnage per 100′: Trap, 39; Local, 35.

CONDITION NO. 2.

Trap Rock — Lower course, No. 1 stone, 19 tons. Upper course, No. 2 stone, 17 tons; screenings for binder, 6 tons.

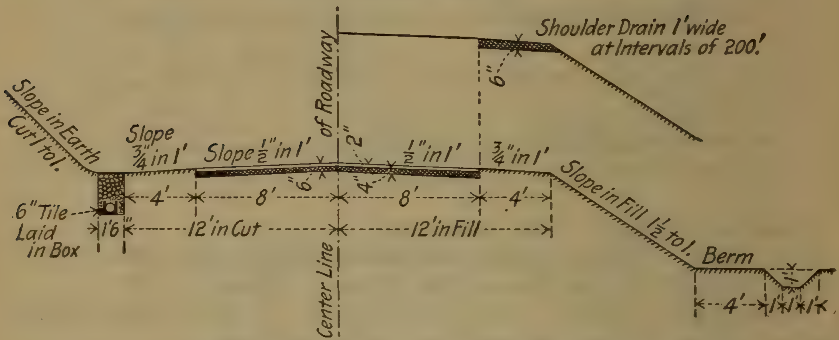
Local Stone — Lower course, No. 1 stone, 17 tons. Upper course, No. 2 stone, 15 tons; screenings for binder, 6 tons.

Total tonnage per 100′: Trap, 42; Local, 38.

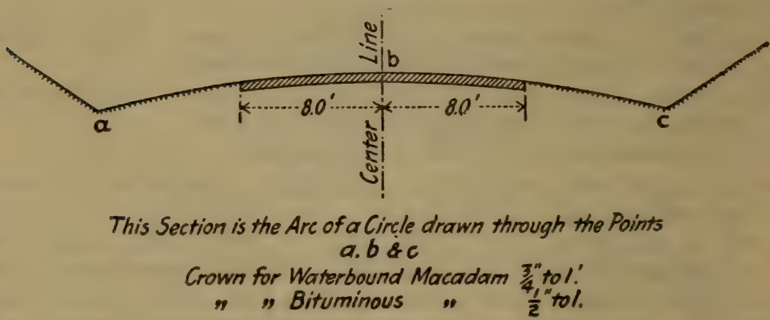
NOTE. — Condition No. 1: Bituminous Treatment — Penetration — lower course bound with stone screenings or sand.

Condition No. 2: Bituminous Treatment — Surface Spraying — screenings of sand binder in upper course.

PLATE 3



State of Washington Standard Section



New Jersey Standard Section

Plates Nos. 1, 2, and 3 show some of the Standard Sections in use at the present time.

Widths of metaling can be discussed at this point, leaving depths for the chapter on "Foundations." There are two sets of widths in general use, 12 ft., 15 ft., 20 ft. and 14 ft., 16 ft., 20 ft.

20 ft. widths are not often required and it is evident that the use of 12 ft. instead of 14 ft. or 15 ft. instead of 16 ft. means a large saving

(see footnote)[1] and is good policy provided the narrower width serves the purpose. There are two ways of approaching this problem. The first is to build the strong metaling just wide enough to comfortably take the heavy traffic, and if the natural shoulder material is not suitable, treat the shoulders to a width of 14′–20′ with gravel, waste #2 stone, or #3 stone filled and rolled but not puddled or tarred, making them suitable and wide enough for the light "turn out traffic"; this method results in the 12′ and 15′ widths. The second way is to make the full depth of the macadam just wide enough to allow two vehicles to pass with a minimum safe clearance, not giving the shoulders any special treatment. This method results in the 14′ width on unimportant roads. The 16′ width is harder to justify, as on the main traveled roads it is wider than necessary for the heavy travel and too narrow for the automobile "turn out traffic."

In the writer's opinion 12′ should be used in preference to 14′ on the side roads where the shoulder material is good or where gravel is cheap or local crushed stone is used, making it possible to get cheap #2 or #3 stone; the 14′ width should be used in preference to 12′ where the shoulder material is bad and gravel or stone are imported. On the main roads 15′ is as satisfactory as 16′ and is cheaper under all conditions, because the 16′ width does not overcome the necessity for a good shoulder.

The importance of shoulder treatment on the side roads should not, however, be overestimated. One of the New York State Highway engineers made a trip from Albany to Binghamton (130 miles) in the Fall of 1910 and counted the rigs he passed; they averaged one every four miles outside of the villages; from this it would seem that for roads of this class shoulder treatment is not worth while unless fine shifting sand or heavy clay is encountered.

The sketches given below show a number of variations of section for bituminous macadam which are applicable to special conditions. Figure 3 shows the distribution of stone on unimportant road sections.

Figure 4 gives a good typical section for ordinary conditions on a main road.

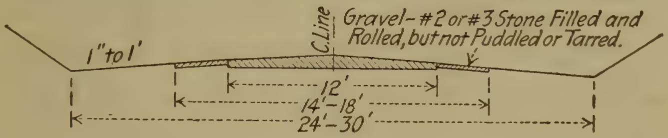


FIG. 3.— Bituminous Macadam

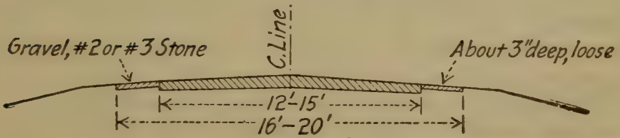


FIG. 3 A.— Shoulder Treatment

[1] The amount saved per mile, assuming a depth of macadam of 6″ and an average price of stone at $3.50 per cu. yd. in place would be approximately $700.00 for use of 12′ in place of 14′ and $350.00 for use of 15′ in place of 16′.

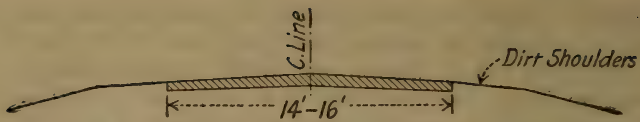


FIG. 3 B. — No Shoulder Treatment

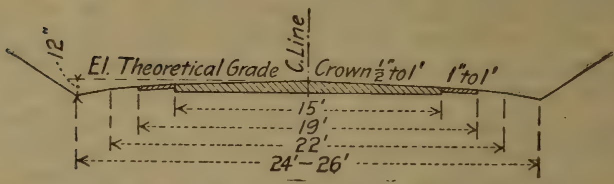


FIG. 4. — Bituminous Macadam

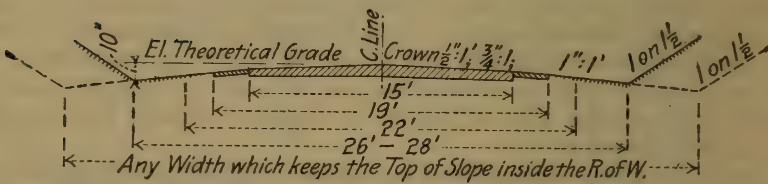


FIG. 5

Figure 5 shows a section adapted to the top of hills where a small amount of surface water is expected. If for any reason it is not practicable to cut into the hill beyond a certain depth and more dirt is needed for fill than is given by the 26′ section at this depth, the shoulders can be widened, provided the tops of the slopes keep within the right-of-way. It is always best to use as shallow a ditch as possible, as it simplifies the construction and maintenance of entrances to the abutting properties.

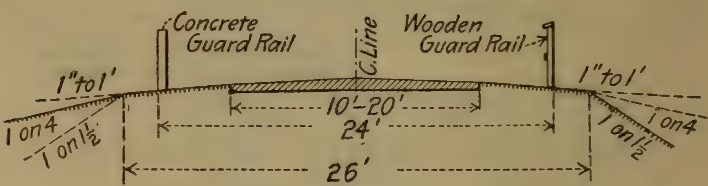


FIG. 6

Figure 6 gives a section showing the variations in fill. A slope of 1″ to 1′ beyond the 22′ width is used on shallow fills; a side slope of 1 on 4 is used for all ordinary fills up to a 7′ depth; beyond a 7′ depth it is cheaper to erect and maintain guard-rail, using a 1 on 1½ slope. The cost of guard-rail is taken up under "Minor Points."

The section shown in Figure 7 is used for unusually heavy cuts to keep the excavation down as much as possible; it should never be used on a sharp curve because of the difficulty in seeing ahead. (See Alignment, page 18, and Office Practice, page 208.)

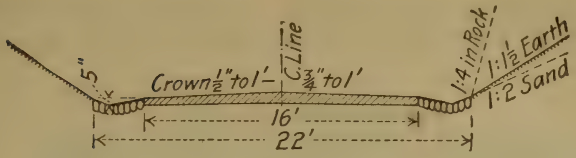


FIG. 7

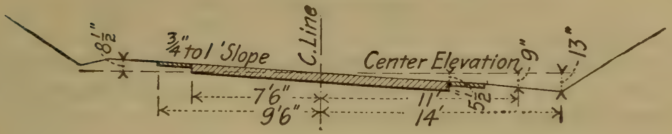


FIG. 8. — Banked Section in Excavation

Figure 8 shows a section well suited for sharp curves on steep grades; the slope of ¾″ to 1′ is not objectionable for slow traffic up the hill and makes easier riding for vehicles traveling rapidly down grade; this section has also been used successfully on sharp curves on level grades and is becoming a standard feature of the New York State work.

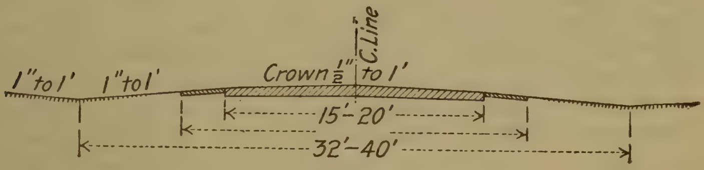


FIG. 9

Figure 9 is a satisfactory village section and by the use of a variable width can be made to fit conditions on most streets.

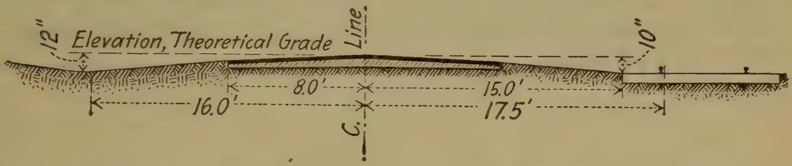


FIG. 10. — Bituminous Macadam Tracks on Side

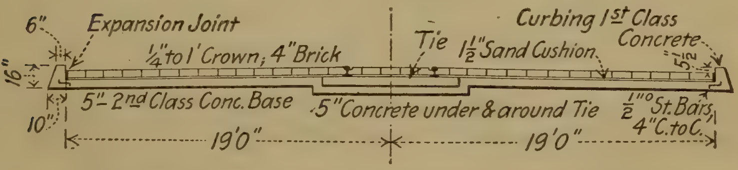


FIG. 10 A. — Village Street, Brick Pavement. Tracks in center, "T"-Rail Special Grooved Brick

The preceding discussion attempts to show only the main points to be considered, for every road presents local conditions peculiar to

itself that require special solutions. However, if the Engineer keeps these points in mind, he will make an economical and appropriate design.

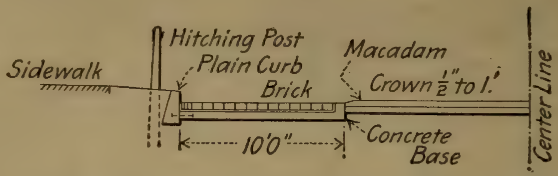


FIG. 11. — Village Section. Combined Brick and Macadam Section in Front of Stores, where Horses will be Hitched Close to the Curb. Prevents Pawing up the Macadam

It may be said in closing that many of the road widths, as actually built, do not represent the engineering judgment of the Highway Departments. On a road where it is evident that a 12′ or 14′ width of metaling would amply serve the traffic there is often a strong sentiment that this locality is being defrauded because some other road is 16′ wide, and if political influence can be successfully used a 16′ width is constructed. This is mentioned to show one of the practical difficulties in attempting to build an *economical* road that meets the actual traffic requirements. The general complaint that roads are becoming more expensive overlooks this contributory cause, and, while it is true that more expensive constructions are necessary on account of changed traffic conditions, it can be safely asserted that in most cases where political expediency overrules engineering judgment, either in regard to widths or materials, an unnecessary expense is incurred. This condition is, however, sometimes due to defects in the Highway laws which allow too much interference by local officials who are not qualified to judge in such matters, and it has been demonstrated that better results are obtained by centralizing the control of the design, particularly in regard to widths, alignment, and materials, in some executive or commission, which is as independent as possible of such local pressure.

CHAPTER III

CULVERTS — SMALL SPAN BRIDGES — UNDER DRAINS

This chapter deals with the smaller drainage structures only. For the theory and practice of reinforced concrete long-span structures, masonry arches, or steel bridges, the reader is referred to the standard works on those subjects.

The conditions for transverse surface drainage to the ditches were given in chapter II and the minimum ditch grades that insure the longitudinal drainage were mentioned under the heading of "Minimum Grades," page 11. Ditches on steep grades must be protected from wash by cobble paving, cement gutters, or loose stone, and these designs are considered under "Minor Points," page 115.

I. Culverts

Engineers do not differ much in the design of these structures. They should be permanent; should be large enough to take the maximum flood flow; should, if possible, be self-cleaning; must admit of being cleaned easily, when necessary, and must be long enough to include the normal width of section between parapets. There is nothing more unsightly and dangerous than to have the width of roadway narrowed at a culvert.

Cast-iron pipe or reinforced concrete boxes are generally used. Cast-iron pipe culverts larger than 18″ are rarely designed, as they are not economical. (See Table No. 17, page 58.) Vitrified pipe should never be placed under the roadbed proper unless encased in concrete; even then cast-iron pipe is preferable and probably cheaper. Where the head room is small, usual practice calls for cast-iron pipe, and if the flow is large, a double or triple line of pipe may be constructed. For small drainage areas the size of the culvert is determined by the convenience of cleaning, rather than by the discharge capacity. Where sufficient fall can be obtained to make it self-cleaning, a 12″ pipe is feasible, but where the flow is sluggish, nothing less than a 16″ or 18″ pipe will serve satisfactorily.

The self-cleaning velocity of flow for sand and earth particles is about one foot per second; for coarse gravel about three feet per second (Ogden's Sewer Design, page 134). A pipe laid on a slope that gives a velocity of five feet per second when flowing one-quarter full should keep clean; this requires a fall of approximately two feet in one hundred for a 12″ pipe, and is the minimum grade at which the 12″ size should be used.

For the smaller concrete culverts the shape of the opening should be designed to allow the use of collapsible forms.

The desired size of a culvert is usually determined in the field by noting the dimensions of the old culvert, if any, and by inquiries of the neighboring residents and the road commissioner as to how the

existing structure has handled the water in the past; any such conclusion should be checked by computing the probable maximum run-off from the area tributary to the culvert. For the convenience of designers, Table No. 10 is given, showing the approximate maximum run-off for small watersheds in flat, rolling, and hilly country. Of course, it is understood that such a table is to be used simply as a guide for judgment.

TABLE 10. MAXIMUM RUN-OFF FOR SMALL WATERSHEDS USING DICKENS' FORMULA

$D = C\sqrt[4]{M^3}$. RUN-OFF EXPRESSED IN SECOND FEET

Area in Square Miles	Flat Country C 200	Rolling Country C 250	Hilly Country C 300
0.1 = 64 acres	36	45	54
0.2	60	75	90
0.3	81	101	121
0.4	100	125	150
0.5	119	149	180
0.6	136	170	204
0.7	153	191	229
0.8	169	211	253
0.9	185	231	277
1.0	200	250	300
2.0	334	417	501
3.0	456	570	684
4.0	564	705	846
5.0	668	835	1002
6.0	764	955	1146
7.0	860	1075	1290
8.0	950	1188	1426
9.0	1038	1297	1556
10.0	1122	1402	1682
20.0	1890	2362	2834
30.0	2560	3200	3840
40.0	3180	3975	4770
50.0	3760	4700	5640
60.0	4310	5400	6480
70.0	4840	6050	7260
80.0	5360	6700	8040
90.0	5840	7300	8760
100.0	6320	7900	9480

For areas under 0.1 square mile, see Table 12.

Dickens' formula takes into consideration the rate of rainfall and character of the catchment basin by the coefficient "C" and is as reliable as any of the maximum run-off formulæ. Wilson in his "Irrigation Engineering," page 19, gives the following values of "C":

Rainfall 3.5 to 4 inches in 24 hours.			
Flat country	C	200	These values are safe for the Northern and Eastern Atlantic States.
Mixed "	C	250	
Hilly "	C	300	

Rainfall 6 inches in 24 hours.		
Flat country	C	300
Mixed "	C	325
Hilly "	C	350

TABLE 11. NEW YORK CENTRAL AND HUDSON RIVER R.R. CULVERTS FOR SMALL DRAINAGE AREAS

Steep, Rocky Ground. Acres	Flat Cultivation, Long Valley. Acres	Size. Diameter in Inches	Equivalent Capacity. Pipes
5	10	10″	
10	20	12″	
20	40	16″	
25	50	18″	two 16″ pipes
30	60	20″	two 16″ pipes
45	90	24″	two 18″ pipes
70	140	30″	two 24″ pipes
110	220	36″	two 30″ pipes
150	300	42″	two 30″ pipes
180	360	48″	two 36″ pipes
280	560	60″	

NOTE. — To be used only in the absence of more reliable information, particularly existing culverts over the same stream.

TABLE 11 A. CULVERT DESIGN. IOWA STATE HIGHWAY COMMISSION[1]

Size of Culvert Opening	Maximum Acres	Minimum Acres
2′ × 2′	70	28
4′ × 4′	376	140
6′ × 6′	1300	520
8′ × 8′	2700	1120
10′ × 10′	5000	2000

Types of Structures Used[1]

1. Box culverts and slab bridges 2′ to 20′ span. Not economical over 20′ span.
2. Reinforced concrete arches 8′ to 100′. Constant tendency to destroy by temperature strains and settlement.
3. Pony truss steel bridges. 30′ to 80′ span with reinforced concrete floor. Adapted to districts where concrete materials are scarce.
4. Reinforced concrete girders, 20′ to 50′ span. Very economical, but require careful design. Not economical for spans over 50′.

Where the road runs through a village, a closer computation may be obtained by using a sewer run-off formula.

The Burkle-Ziegler formula for such approximations is as follows:

$$\left.\begin{array}{l}\text{Cubic ft. per sec.}\\ \text{per acre reaching}\\ \text{culvert}\end{array}\right\} = C \times \left\{\begin{array}{l}\text{Av. cu. ft. of}\\ \text{rainfall per sec.}\\ \text{per acre during}\\ \text{heaviest fall}\end{array}\right\} \times \sqrt[4]{\frac{\begin{array}{l}\text{Av. slope of ground}\\ \text{in ft. per 1000}\end{array}}{\text{No. of acres drained}}}$$

C = 0.75 for paved streets and built up business blocks.
C = 0.625 for ordinary city streets.
C = 0.30 for villages with gardens, lawns, and macadamized streets.

Trautwine states that 1″ of rainfall per hour equals 1 cu. ft. per second per acre approximately.

For drainage areas of under 1 square mile, it is probably better to use the Burkle-Ziegler formula even for farming country, using the coefficient C = 0.25.

Table 12 shows the amount of run-off computed by this formula assuming a maximum rainfall rate of 4″ per hour for the constants C = 0.30 and C = 0.25 for areas up to 1 square mile.

Note: — Quantities in Tables 10, 12, and 13 computed and checked by slide-rule; sufficiently accurate for the purpose for which these tables are intended.

Table 13 gives the velocity of flow and the discharge capacity of pipe and box culverts for different rates of fall per 100 feet.

Examples of the use of tables 10 to 13 in checking culvert sizes.

1. Determine the character and area of watershed tributary to culvert; say rolling country, one square mile.
2. Determine flood flow for this area of rolling country from Table No. 10; equals 250 second feet.
3. From the profile of the stream where it crosses the road determine the fall in feet per 100; say 1.0 ft.
4. In Table 13 opposite 1.0 ft. in the "Rate of Fall" column, pick out the size that has a discharge capacity of 250 second feet; equals 4′ x 4′ culvert.

Where the road runs through a depression which has no outlet, a culvert should be placed at the lowest point to keep the water at the same elevation on both sides of the road, and the grade line raised above high-water level.

It is our opinion that a culvert should have the same slope as the stream bed. If given a greater slope the outlet end tends to clog, and if a lesser the inlet end will plug. It is unusual for culverts to fill badly, except when placed at the foot of a steep hill where the

[1] See Table at foot of p. 35.

stream velocity is naturally reduced. At such points an extra large structure should be designed with the idea of providing sufficient waterway even after the contraction caused by this settlement has occurred. Such a culvert should be cleaned after each freshet.

More trouble is experienced from culverts becoming filled with ice due to alternate freezing and thawing weather; this is particularly true of small culverts draining springs. Culverts as large as 2'x 2' have frozen solid in this manner, and if this condition is anticipated the size should be regulated accordingly or trouble will be experienced during the Spring break-up.

In designing culverts under side roads, the length must be great enough to provide an easy turn; many times a saving in length can be made by placing the culvert a short distance down the side road, as shown in figure No. 12, page 39.

TABLE 12. RUN-OFF FOR SMALL AREAS

Discharge in cu. ft. per second for a maximum rainfall rate of 4 inches per hour.

Area in Acres	Fall of 5' in 1000		Fall of 20' in 1000		Fall of 50' in 1000	
	C = 0.30	C = 0.25	C = 0.30	C = 0.25	C = 0.30	C = 0.25
1	1.8	1.5	2.5	2.1	3.1	2.7
2	3.0	2.5	4.2	3.5	5.4	4.5
3	4.1	3.4	5.7	4.8	7.2	6.0
4	5.0	4.2	7.2	6.0	9.0	7.5
5	6.0	5.0	8.5	7.1	10.7	8.9
6	6.8	5.7	9.7	8.1	12.2	10.2
7	7.7	6.4	10.9	9.1	13.7	11.4
8	8.5	7.1	12.0	10.0	15.1	12.6
9	9.3	7.8	13.2	11.0	16.5	13.8
10	10.1	8.4	14.3	11.9	18.0	15.0
20	16.9	14.1	24.0	20.0	30.2	25.2
30	23.0	19.2	32.5	27.1	40.7	33.9
40	28.5	23.8	40.3	33.6	50.9	42.4
50	33.6	28.0	47.7	39.8	60.0	50.0
60	38.6	32.2	54.6	45.5	68.7	57.3
70	43.3	36.1	61.4	51.2	77.3	64.4
80	48.0	40.0	67.9	56.6	85.2	71.0
90	52.4	43.7	73.9	61.6	93.1	77.6
100	56.7	47.3	80.2	66.8	100.8	84.0
200	95.4	79.5	134.6	112.2	169.7	141.4
300	129.0	107.7	182.9	152.4	229.7	191.4
400	160.0	133.6	227.0	189.2	285.6	238.0
500	190.0	158.0	268.0	223.5	336.6	280.5
600	216.0	180.0	307.0	256.0	387.3	322.8
640 } 1 sq. mile }	230.0	[1]192.0	323.0	269.0	406.3	338.6

[1] 200 second feet by Dickens' formula, Table 10.

TABLE 13.—APPROXIMATE DISCHARGE CAPACITY CAST-IRON PIPE AND SMALL CONCRETE BOX CULVERTS

Slope in Feet per 100	12″ C. I. P.		14″ C. I. P.		16″ C. I. P.		18″ C. I. P.		20″ C. I. P.		22″ C. I. P.		24″ C. I. P.	
	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.
0.5					4.5	6	5.0	9	5.4	12	5.8	15	6.2	19
1.0					6.8	9	7.0	12	7.7	17	8.2	22	9.2	29
2.0	7.4	6	8.3	9	9.2	13	10.0	18	10.9	24	11.5	30	12.3	39
3.0	9.2	7	10.3	11	11.2	16	12.2	21	13.4	29	14.2	37	14.8	46
4.0	10.6	8	11.8	12	13.1	18	14.2	25	15.3	34	16.5	43	17.2	54
5.0	11.8	9	13.3	14	14.6	20	16.2	28	17.3	38	18.0	48	19.0	60
6.0	13.0	10	14.6	15	16.2	23	17.5	31	19.0	41	20.0	53	21.3	67
Area Sq. Ft.	0.78		1.07		1.39		1.76		2.17		2.64		3.14	
Value of R	0.25		0.29		0.33		0.37		0.42		0.46		0.50	

Velocity in Feet per Second; Discharge in Cu. Ft. per Second

CONCRETE BOXES

Slope in Feet per 100	2′ × 1.5′		2′ × 2′		3′ × 2′		3′ × 3′		4′ × 2′		4′ × 3′		4′ × 4′		5′ × 3′		5′ × 4′		5′ × 5′	
	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.
0.5	7.0	21	7.7	31	8.6	52	9.7	87	9.7	78	10.8	130	11.6	186	11.9	179	13.0	260	13.8	340
1.0	10.0	30	10.4	42	12.5	75	13.7	123	13.7	110	15.0	180	16.7	267	16.9	254	18.5	370	19.0	475
2.0	14.0	42	14.8	59	17.5	105	19.0	171	19.0	152	22.0	264	23.6	378	23.8	357	26.2	523	28.0	700
3.0	17.2	52	18.3	73	21.6	130	23.5	212	23.5	188	26.5	318	29.0	464	29.5	443				
4.0	20.0	60	21.0	84	24.8	149	27.5	248	27.0	216	30.5	366								
5.0	22.6	68	23.5	94	27.5	165	31.0	279	31.0	248										
6.0	24.0	72	26.0	104	30.0	180														
Area Sq. Ft.	3.0		4.0		6.0		9.0		8.0		12.0		16.0		15.0		20.0		25.0	
Value of R	0.60		0.66		0.86		1.0		1.0		1.2		1.33		1.36		1.54		1.66	

Note: — Table 13 is figured from Church's diagrams of Kutters formula using n = 0.011; the use of these diagrams for short culverts is approximate only but it is sufficiently close for the purposes for which this table is intended.

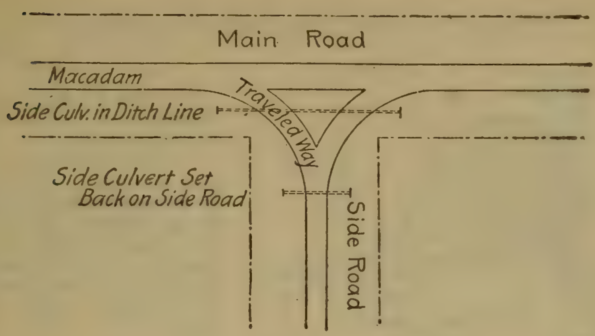


FIG. 12

The following section shows a form of culvert often used in village streets where deep ditches at the culvert site would be objectionable:

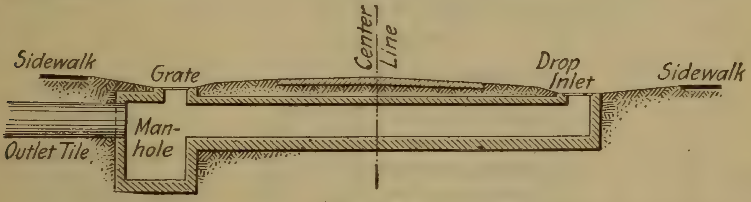


FIG. 13

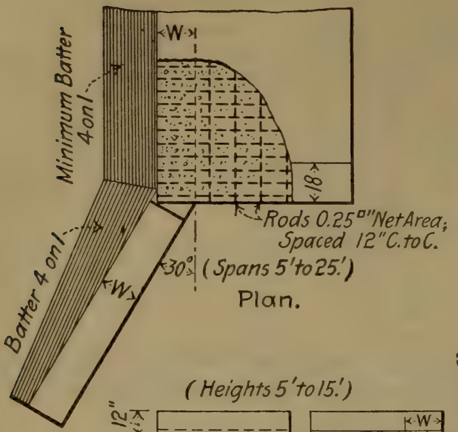
For the small-sized structures required to carry ditch drainage under driveways vitrified tile well laid is as suitable as any style of construction; the wooden boxes built by some Departments are not economical, which is shown in the following estimate of relative cost of small culverts, given by A. R. Hirsch in Wisconsin Road Pamphlet No. 4:

Kind	Size of Opening	Length	First Cost and Maintenance for 100 Years
3″ Hemlock box	15 in. sq.	24′	$252.00
Concrete box	15 in. sq.	20′	40.00
Concrete pipe	18 in.	20′	35.00
Single strength V. T. P. .	18 in.	30′	41.00
Double strength V. T. P. .	18 in.	28′	42.00
Cast-iron pipe	18 in.	24′	166.00
Corrugated steel	18 in.	26′	196.00

SMALL SPAN, SOLID FLOOR BRIDGES

Under this head are included spans of 5 to 25 feet; they are generally designed from one of three types: reinforced concrete slabs,

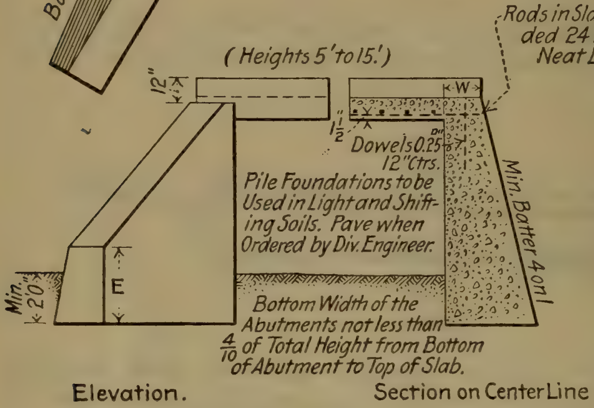
Plate 4.— New York State Slab Bridges



Note

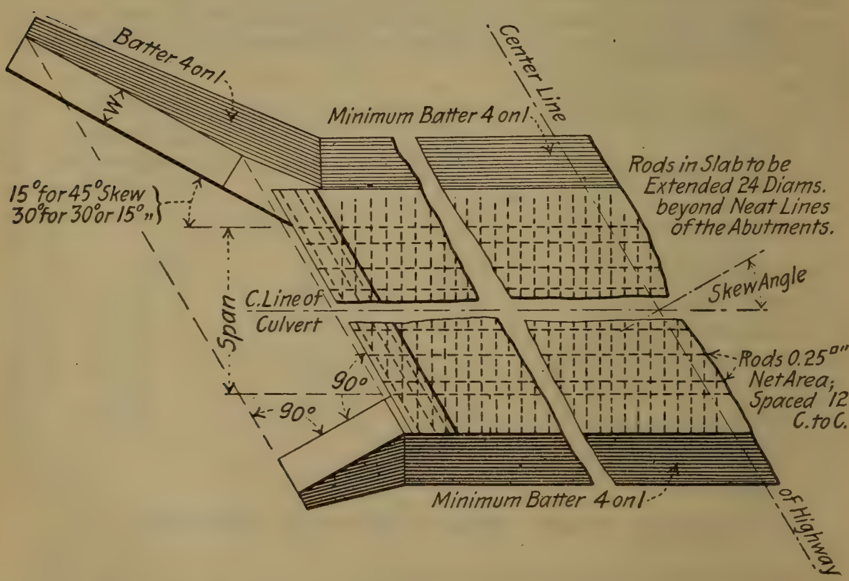
All rods to have a deformed cross-section. All rib metal to be of medium steel.

2d class concrete in all slabs and parapets. 3d class concrete in wings invert and abutments. Wing walls on the outlet end of all square culverts with concrete floors to be built parallel to the center line of the culvert. Round all exposed edges to $1\frac{1}{2}$ inch radius.



For Typical Section "F"

Where culvert covers become a part of concrete base for brick pavement, transverse reinforcement should be extended 12″ beyond back of abutment into concrete base.



Span	Thickness of Slab	Net Area of Rods	Rod Spacing C–C	Length of Dowels
5	8″	0.25sq.″	$4\frac{1}{2}$″	12″
6	9″	"	4″	"
7	10″	0.39sq.″	$5\frac{3}{4}$″	"
8	10″	"	$5\frac{1}{4}$″	"
9	11″	"	5″	"
10	12″	"	$4\frac{3}{4}$″	"
11	12″	0.56sq.″	$6\frac{1}{4}$″	"
12	13″	"	6″	18″
13	13″	"	$5\frac{3}{4}$″	"
14	14″	"	$5\frac{3}{8}$″	"
15	14″	"	5″	"
16	15″	"	$4\frac{3}{4}$″	"
17	15″	"	$4\frac{3}{4}$″	"
18	16″	"	$4\frac{1}{2}$″	"
19	17″	"	$4\frac{1}{4}$″	"
20	18″	0.77sq.″	$5\frac{1}{4}$″	"
21	18″	"	$5\frac{1}{4}$″	"
22	19″	"	5″	24″
23	19″	"	5″	"
24	20″	"	$4\frac{5}{8}$″	"
25	21″	1.00sq.″	$5\frac{7}{8}$″	"

For Spans 5′ to 19′ W = 18″ For Clear Height 10′ or less
" " 5′ to 19′ W = 24″ " " " 11′ to 15′
" " 20′ to 25′ W = 24″ " " " 15′ or less
For Clear Height 7′ or less E = 3′-0″
" " " 8′ to 10′ E = 4′-0″
" " " above 10′ E = 5′-0″

steel I-beam stringers supporting thin reinforced concrete floor slabs, or plain and reinforced concrete arches.

Central piers will often reduce the cost of culverts having a long span with small height.

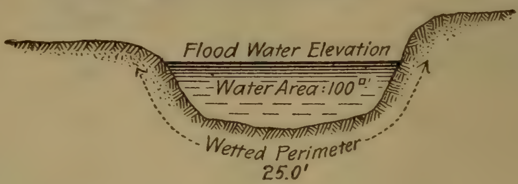
For structures of this class more care must be taken in determining the span and height. On streams requiring spans of more than 10 feet there are generally existing structures above and below the proposed bridge site which will afford the best basis for judgment. While it is usually good policy not to reduce the span of an existing structure it is often found that the present bridge, particularly if it is a steel bridge that has been sold to the town by an enterprising bridge company, has a needlessly long span.

If the freshet velocity of the stream is high the stream bed and the abutment foundations may be protected from scour by riprap. However, it is not often necessary to take this precaution for small span bridges. According to Trautwine a velocity of eight miles an hour, or 12′ per second, will not derange quarry rubble-stones exceeding half a cu. ft. deposited around piers or abutments. A rough approximation of small stream velocities can be made by assuming a value of 60 for the constant C in the formula $V = C\sqrt{RS}$ where V = velocity of flow in feet per second; constant C = 60.

$$R = \text{Hydraulic radius} = \frac{\text{Cross sectional area of flow}}{\text{Wetted Perimeter.}}$$

S = slope of stream.

Example. To approximate the freshet velocity of the stream shown having a fall of 1.0′ per 100′, or 53′ per mile



$$V = C\sqrt{RS}$$

$$C = 60$$

$$R = \frac{100}{25} = 4$$

$$S = \frac{1}{100} = 0.01$$

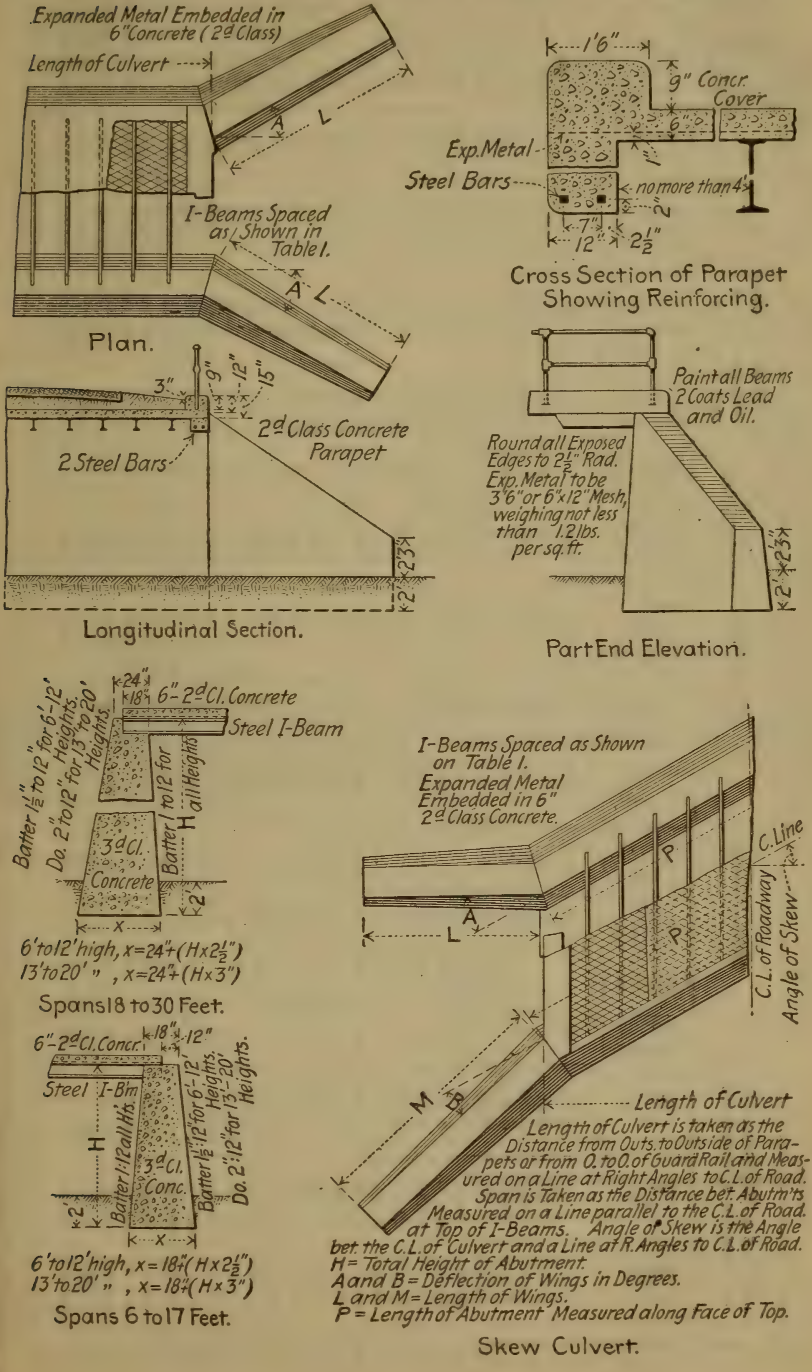
$$V = 60\sqrt{4 \times 0.01} = 60\sqrt{.04} = 60 \times .2 = 12 \text{ ft. per second.}$$

Plates No. 4 to No. 6 c show the standards for culverts and small bridges as used by various State Departments.

Under Drainage

The purpose of under drains is to intercept the ground water before it reaches and softens the subgrade. On a side hill road the drain is usually placed under the ditch on the up-hill side (see Figure No. 14, position No. 1, page 52), where the greatest depth can be obtained

PLATE 4 A. — New York State I-Beam Bridges



Plan.

Cross Section of Parapet Showing Reinforcing.

Longitudinal Section.

Part End Elevation.

Spans 18 to 30 Feet.

Spans 6 to 17 Feet.

Skew Culvert.

Table No. 1 PLATE 4 A. — QUANTITIES IN CULVERTS FOR 25 FOOT LENGTH AND FOR 1 FOOT OF LENGTH

Span, all Culverts	Opening at Right Angles to Faces of Abutments			Steel I-Beams					Steel Bars		Sq. feet E'x'p'dMet.		Cu. Yds. 2d Class Concrete Cover and Parapets		Ft. B. M. Lumber		Pounds Spikes and Nails	Lin. ft. Bridge Rail	Lin. ft. Pipe Rail
	15° Skew	30° Skew	45° Skew	Depth Inches	Spacing	Length feet	Wt. per ft.	Wt. of Beam	Size	Weight of 4 Bars	25 foot Length	Per foot Length	25 foot Length	Per foot Length	25 foot Length	Per foot Length			
6	5.80	5.20	4.24	6		8	12¼	100	¾″	61	200	8	4.54	0.15	855	30	24	20	16
7	6.76	6.06	4.95	7		9	15	135	¾″	69	225	9	5.08	0.17	952	33	26	22	18
8	7.73	6.93	5.66	7		10	15	150	¾″	76	250	10	5.63	0.19	1042	36	28	24	20
9	8.69	7.79	6.36	8	2′-9″	11	18	198	¾″	84	275	11	6.63	0.20	1143	39	30	26	22
10	9.66	8.66	7.07	9	3′-0″	12	21	252	¾″	92	300	12	7.28	0.22	1234	42	32	28	24
11	10.63	9.53	7.78	9	3′-0″	13	21	273	⅞″	135	325	13	7.88	0.24	1325	45	34	30	26
12	11.59	10.39	8.49	9	2′-6″	14	21	294	⅞″	146	350	14	8.48	0.26	1431	48	36	32	28
13	12.56	11.26	9.19	10	3′-0″	15	25	375	1 ″	204	375	15	9.16	0.28	1523	51	38	34	30
14	13.52	12.12	9.90	10	2′-9″	16	25	400	1 ″	218	400	16	9.78	0.30	1633	54	40	36	32
15	14.49	12.99	10.61	12	3′-0″	17	31½	535½	1 ″	231	425	17	10.56	0.31	1727	57	42	38	34
16	15.45	13.86	11.31	12	3′-0″	18	31½	567	1 ″	245	450	18	11.19	0.33	1820	60	44	40	36
17	16.42	14.72	12.02	12	3′-0″	19	31½	598½	1⅛″	327	475	19	11.81	0.35	1956	63	46	42	38
18	17.39	15.59	12.73	12	3′-0″	21	31½	661½	1⅛″	361	525	21	12.90	0.39	2052	66	48	44	40
19	18.35	16.46	13.44	12	2′-9″	22	31½	693	1⅛″	378	550	22	13.51	0.41	2148	69	50	46	42
20	19.32	17.32	14.14	15	3′-0″	23	42	966	1⅛″	396	575	23	14.51	0.43	2244	72	52	48	44
21	20.28	18.19	14.85	15	3′-0″	24	42	1008	1¼″	510	600	24	15.14	0.44	2340	75	54	50	46
22	21.26	19.05	15.56	15	3′-0″	25	42	1050	1¼″	531	625	25	15.79	0.46	2519	78	56	52	48
23	22.22	19.92	16.26	15	3′-0″	26	42	1092	1¼″	552	650	26	16.43	0.48	2618	81	58	54	50
24	23.18	20.78	16.97	15	3′-0″	27	42	1134	1⅜″	694	675	27	17.08	0.50	2718	84	60	56	52
25	24.15	21.65	17.68	15	2′-9″	28	42	1176	1⅜″	720	700	28	17.72	0.52	2818	87	62	58	54
26	25.11	22.52	18.38	15	2′-6″	29	42	1218	1½″	887	725	29	18.36	0.54	2918	90	64	60	56
27	26.08	23.38	19.09	18	3′-0″	30	55	1650	1½″	918	750	30	19.50	0.56	3018	93	66	62	58
28	27.05	24.25	19.80	18	3′-0″	31	55	1705	1½″	949	775	31	20.16	0.57	3222	96	68	64	60
29	28.01	25.11	20.51	18	3′-0″	32	55	1760	1½″	979	800	32	20.82	0.59	3326	99	70	66	62
30	28.98	25.98	21.23	18	3′-0″	33	55	1815	1½″	1010	825	33	21.48	0.61	3430	102	72	68	64

NOTE: Length of Bars in Parapets same as lengths of I-Beams.

PLATE 4 A — *continued*

Table No. 2			STRAIGHT A = 30° B = 30°						*Table No. 3*		15° SKEW A = 30° B = 15°					
Height of Abutment	Lengths of Wings		Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culvert more or less than 25 ft.		Lengths of Wings		Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culvert more or less than 25 ft.	
H	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry
6	3.87	3.87	23.3	5.5	28.5	6.5	0.94	1.17	3.51	3.67	24.2	5.2	29.7	6.1	0.98	1.21
7	5.60	5.60	28.3	9.2	34.3	10.9	1.17	1.41	5.06	5.40	29.6	8.8	36.0	10.4	1.20	1.47
8	7.33	7.33	34.0	13.8	40.5	16.4	1.38	1.68	6.62	7.13	35.4	12.9	42.7	15.5	1.44	1.74
9	9.06	9.06	40.0	19.4	47.3	22.7	1.63	1.95	8.16	8.86	41.6	18.3	49.6	21.6	1.69	2.03
10	10.79	10.79	46.4	25.4	54.5	30.2	1.88	2.25	9.72	10.59	48.2	24.3	57.2	28.8	1.95	2.33
11	12.52	12.52	53.3	33.4	62.3	39.1	2.16	2.56	11.27	12.32	55.2	31.7	65.1	37.1	2.24	2.66
12	14.26	14.26	60.8	42.1	70.5	49.1	2.44	2.89	12.82	14.06	62.5	39.9	73.5	46.6	2.54	3.00
13	15.99	15.99	72.2	55.5	84.7	64.3	3.01	3.49	14.38	15.79	76.8	53.0	88.4	61.3	3.12	3.62
14	17.72	17.72	81.5	68.4	94.2	78.5	3.37	3.89	15.53	17.52	86.0	64.5	98.6	74.4	3.50	4.04
15	19.45	19.45	91.0	82.4	104.2	94.0	3.75	4.31	17.48	19.25	95.7	78.4	109.3	89.6	3.89	4.47
16	21.18	21.18	101.0	98.2	114.5	111.4	4.15	4.74	19.11	20.98	106.0	93.7	120.5	106.3	4.31	4.92
17	22.92	22.92	111.1	115.9	125.3	130.7	4.56	5.19	20.58	22.72	116.1	110.1	131.8	124.5	4.74	5.39
18	24.65	24.65	121.8	134.4	136.3	152.6	5.00	5.67	22.14	24.45	127.1	128.8	143.7	145.0	5.19	5.88
19	26.38	26.38	132.7	156.2	147.7	175.7	5.45	6.16	23.69	26.18	138.3	149.0	155.8	167.3	5.66	6.38
20	28.11	28.11	144.0	179.5	159.5	201.4	5.93	6.67	25.24	27.91	150.2	170.8	168.4	191.6	6.15	6.91

PLATE 4 A — *continued*

Table No. 4			30° SKEW A = 30° B = 15°						*Table No. 5*		45° SKEW A = 45° B = 0°					
Height of Abutment	Lengths of Wings		Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culverts more or less than 25 ft.		Lengths of Wings		Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culvert more or less than 25 ft.	
H	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry
6	3.4	4.44	27.0	5.6	33.3	6.8	1.09	1.35	3.6	4.24	33.0	5.5	40.5	6.8	1.34	1.65
7	4.9	6.56	32.8	8.8	40.2	11.3	1.33	1.63	5.1	6.36	40.5	9.7	49.5	11.2	1.63	2.00
8	6.4	8.69	39.5	14.4	47.6	17.0	1.59	1.94	6.6	8.49	48.3	14.5	58.8	17.1	1.95	2.37
9	7.9	10.81	46.3	20.2	55.7	23.8	1.87	2.26	8.1	10.81	57.0	20.3	68.5	23.8	2.29	2.76
10	9.4	12.93	53.7	26.9	64.0	31.7	2.17	2.60	9.6	12.73	66.0	27.2	78.5	31.8	2.66	3.18
11	10.9	15.05	61.6	34.7	72.9	40.9	2.48	2.95	11.1	14.85	75.4	35.0	89.2	41.0	3.04	3.63
12	12.4	17.17	70.0	43.7	82.3	51.4	2.82	3.34	12.6	16.97	85.5	44.1	100.5	51.4	3.46	4.09
13	13.9	19.30	85.7	58.3	99.2	67.5	3.48	4.03	14.1	19.10	105.0	58.8	121.5	67.9	4.26	4.94
14	15.4	21.42	96.0	71.4	110.7	82.8	3.89	4.49	15.6	21.22	117.6	71.8	135.3	83.0	4.76	5.50
15	16.9	23.54	107.0	86.4	122.4	99.5	4.33	4.97	17.1	23.54	130.8	87.1	149.8	99.4	5.31	6.09
16	18.4	25.66	118.0	102.9	134.6	117.3	4.79	5.48	19.6	25.46	144.7	103.6	165.0	117.4	5.87	6.71
17	19.9	27.78	129.7	121.2	147.0	137.2	5.27	6.00	20.1	27.58	159.0	121.6	180.6	137.8	6.46	7.35
18	21.4	29.90	142.0	141.1	160.5	159.7	5.77	6.54	21.6	29.70	173.0	141.8	197.0	159.7	7.08	8.02
19	22.9	32.02	154.6	163.5	174.0	184.4	6.30	7.11	23.1	31.82	189.6	164.1	213.9	184.7	7.72	8.71
20	24.4	34.14	168.0	188.5	188.0	211.2	6.84	7.70	24.6	33.94	206.0	189.1	232.0	211.6	8.39	9.43

PLATE 4 A — *continued*

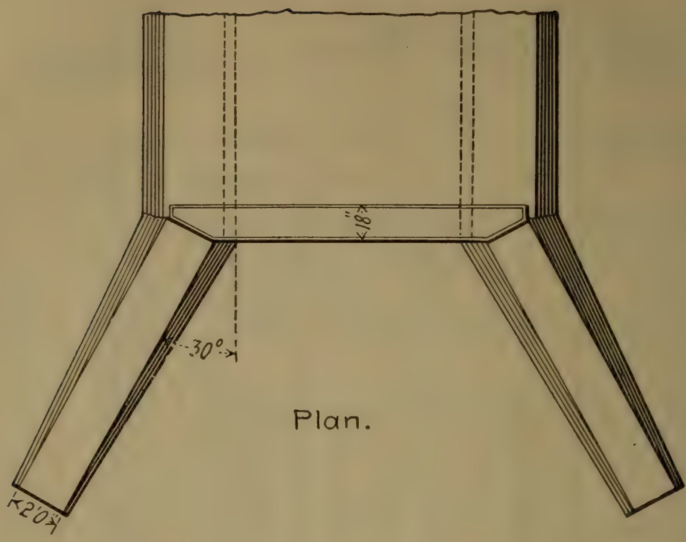
Table No. 6 Length of Culvert	Number I-Beams For Concrete Covers only — Spacing 2′-6″	2′-9″	3′-0″	P = Length of Abutments — 15° Skew	30° Skew	45° Skew
18	5	5	4	18.64	20.79	25.46
19	5	5	5	19.67	21.94	26.97
20	6	5	5	20.71	23.09	28.28
21	6	6	5	21.74	24.25	29.70
22	6	6	5	22.78	25.40	31.11
23	7	6	6	23.81	26.66	32.53
24	7	6	6	24.85	27.71	33.94
25	7	7	6	25.88	28.87	35.36
26	8	8	7	26.92	30.02	36.77
27	8	8	7	27.95	31.18	38.18
28	9	8	7	28.99	32.33	39.60
29	9	8	8	30.02	33.49	41.01
30	9	9	8	31.06	34.64	42.43
31	10	9	9	32.09	35.80	43.84
32	10	9	9	33.13	36.95	45.26
33	11	10	9	34.16	38.10	46.67

APPLICATION OF TABLES

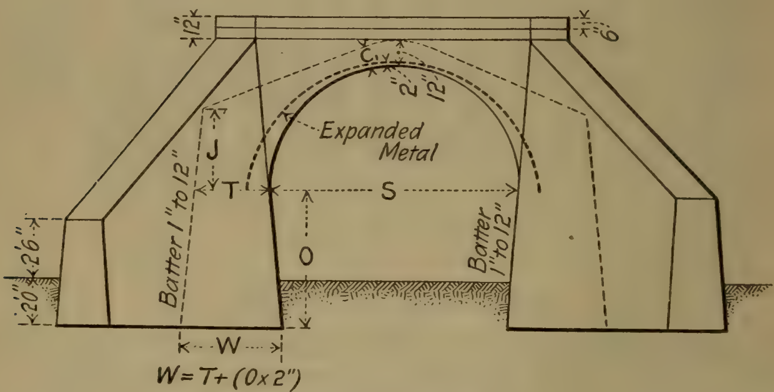
Quantities for a 30° Skew Concrete Culvert, concrete top, length 30 feet, opening 13 feet high and 12 feet wide. From Table 1, an opening 12.12 ft. wide 30° Skew is a 14-ft. span requiring (see 30-ft. length, Table 6) 9 I-Beams spaced 2′-9″ c. to c. (9 × 400) = 3600 lbs. I-Beams; 218 lbs. Bars; 400 + (5 × 16) = 480 sq. ft. Ex'p'd Metal; 9.78 + (5 × 30) = 11.28 cu. yds. 2d class Concrete 32 lin. ft. Pipe Rail. An opening 13 ft. high will require Abutments, 16 ft. high (13′ + 2′ in ground + 10″ I-Beam = 15′-10″). From Table 4, Abutments = 118.0 cu. yds., Wings = 102.9 cu. yds. (5 × 4.79 = 23.95 cu. yds. 5 ft. extra length of Culvert) 118.0 + 102.9 + 23.95 = 244.85 cu. yds. 3d Class Concrete.

For Spans of more than 17 feet, use Masonry Tables for Concrete Abutments and Wings.

PLATE 5



Plan.

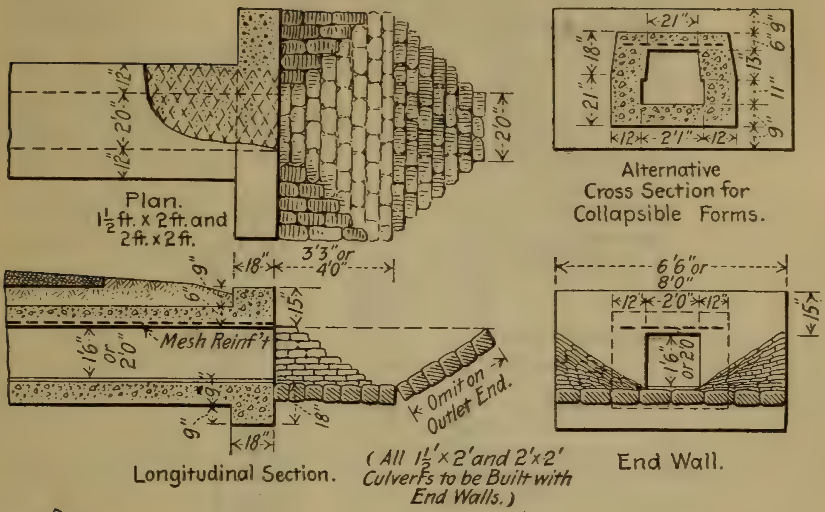


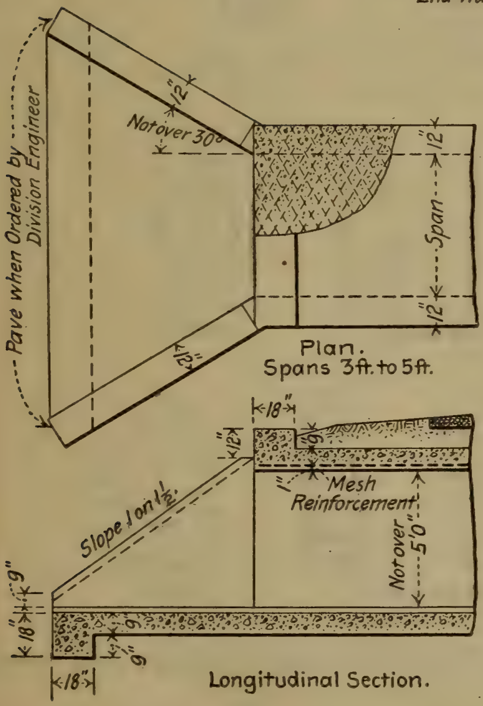
End Elevation.

GENERAL DIMENSIONS SEMI-CIRCULAR ARCH CULVERTS

S Span	Thickness at Springing Line		Thickness of Ring		Height of Haunch	
	T Concrete	K Masonry	C Concrete	R Masonry	J Concrete	V Masonry
6	2′-6″	2′-6″	10″	10″	1′-9″	2′-0″
8	2′-6″	2′-6″	11″	12″	2′-6″	2′-6″
10	3′-0″	3′-0″	12″	12″	3′-0″	3′-0″
12	3′-6″	3′-6″	14″	15″	3′-6″	3′-9″
14	3′-9″	3′-9″	15″	15″	4′-0″	4′-6″
16	4′-0″	4′-0″	16″	15″	4′-8″	5′-0″
18	4′-6″	4′-6″	18″	18″	5′-0″	5′-6″
20	5′-0″	5′-0″	18″	18″	5′-6″	6′-0″

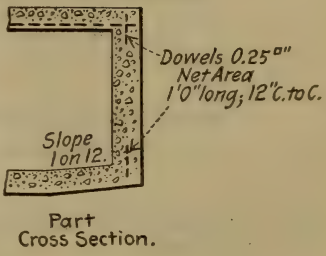
PLATE 6





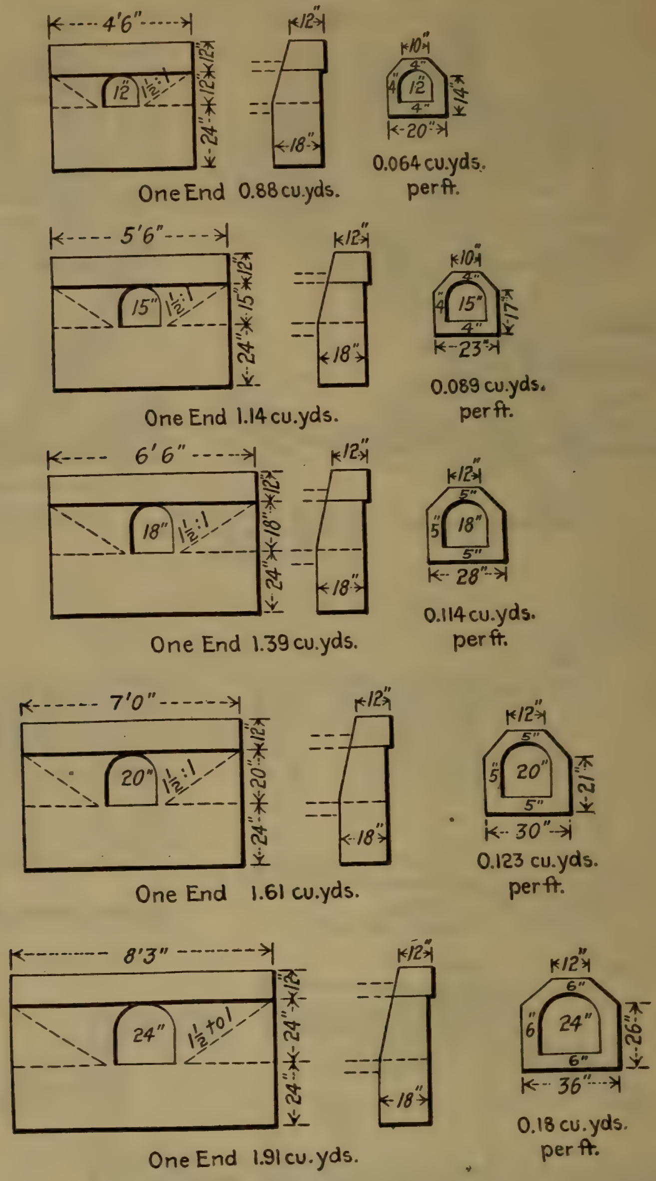
Span	Thickness of Slab	Thickness of Abutment	Mesh Reinforcement. Lbs. per sq. ft.
2'0"	6"	12"	0.6
3'0"	6"	12"	1.2
4'0"	6"	12"	1.2
5'0"	8"	12"	1.2

Table of Dimensions.



New York State Small Box Culverts

PLATE 6 A. — Massachusetts Standard for Concrete Arch Culverts



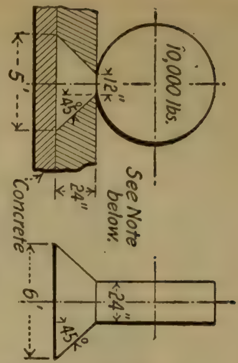
with the least excavation and where the water is caught as it flows out of the hill.

Some engineers place the drain in position No. 2 (figure 14), but this requires more excavation for the same depth, and, in the writer's opinion, it is more likely to be broken.

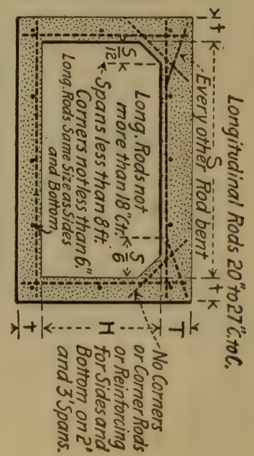
The usual depth for drains is three feet below the surface.

Where the road is on a descending grade, the water will flow out of

PLATE 6 B



Assumption for Live Load.



Cross Section of Culvert.

TABLE FOR STANDARD CULVERTS. Loading 15-Ton Road Roller, 10,000 lbs. on each wheel. Unit stresses 16,000 lbs. for Steel, 600 lbs. for Concrete, 0.7% of Steel. Los Angeles Co. Highway Com., A. E. Loder, Chief Eng.

				Top Reinforcement			Corner Reinforcement			Side Walls Reinforcement			Bottom Reinforcement			Quan. per lineal ft. box.		
D[1]	H[2]	T[3]	t[4]	Size	Spc.	Lgth.	Size	Spc.	Lgth.	Size	Spc.	Lgth.	Size	Spc.	Lgth.	C. Yds Con.	Steel lb.	
8″	1′	4″	4″	3/8″	8″	2′-6″										.091	3.70	2′-Span
8″	2′	4″	4″	3/8″	8″	2′-6″										.115	3.70	
8″	1′	5½″	5″	3/8″	5″	3′-9″										.155	7.17	3′-Span
8″	2′	5½″	5″	3/8″	5″	3′-9″										.186	7.17	
8″	3′	5½″	5″	3/8″	5″	3′-9″										.216	8.12	
8″	1′	6″	5″	1/2″	8″	4′-8″	3/8″	16″	1′-6″	3/8″	16″	1′-9″	3/8″	16″	4′-8″	.204	12.83	4′-Span
8″	2′	6″	5″	1/2″	8″	4′-8″	3/8″	16″	1′-6″	3/8″	16″	2′-9″	3/8″	16″	4′-8″	.235	13.55	
8″	3′	6″	5″	1/2″	8″	4′-8″	3/8″	16″	1′-6″	3/8″	16″	3′-9″	3/8″	16″	4′-8″	.266	15.22	
8″	2′	6½″	5″	1/2″	7″	5′-8″	3/8″	14″	1′-6″	3/8″	14″	2′-9″	3/8″	14″	5′-8″	.278	17.91	5′-Span
8″	3′	6½″	5″	1/2″	7″	5′-8″	3/8″	14″	1′-6″	3/8″	14″	3′-9″	3/8″	14″	5′-8″	.309	19.68	
8″	4′	6½″	5″	1/2″	7″	5′-8″	3/8″	14″	1′-6″	3/8″	14″	4′-9″	3/8″	14″	5′-8″	.339	20.49	
8″	2′	7½″	6″	1/2″	6″	6′-10″	3/8″	12″	1′-9″	3/8″	12″	3′-0″	3/8″	12″	6′-10″	.373	23.23	6′-Span
8″	3′	7½″	6″	1/2″	6″	6′-10″	3/8″	12″	1′-9″	3/8″	12″	4′-0″	3/8″	12″	6′-10″	.410	25.14	
8″	4′	7½″	6″	1/2″	6″	6′-10″	3/8″	12″	1′-9″	3/8″	12″	5′-0″	3/8″	12″	6′-10″	.448	26.10	
8″	2′	8½″	6″	5/8″	8″	8′-10″	1/2″	16″	2′-0″	1/2″	16″	3′-2″	1/2″	16″	8′-10″	.494	38.32	8′-Span
8″	3′	8½″	6″	5/8″	8″	8′-10″	1/2″	16″	2′-0″	1/2″	16″	4′-2″	1/2″	16″	8′-10″	.531	41.30	
8″	4′	8½″	7″	5/8″	8″	9′-0″	1/2″	16″	2′-0″	1/2″	16″	5′-2″	1/2″	16″	9′-0″	.628	43.02	
8″	5′	8½″	7″	5/8″	8″	9′-0″	1/2″	16″	2′-0″	1/2″	16″	6′-2″	1/2″	16″	9′-0″	.671	46.00	
8″	2′	10″	7″	5/8″	6½″	11′-0″	1/2″	13″	2′-6″	1/2″	13″	3′-3″	1/2″	13″	11′-0″	.700	54.90	10′-Span
8″	3′	10″	7″	5/8″	6½″	11′-0″	1/2″	13″	2′-6″	1/2″	13″	4′-3″	1/2″	13″	11′-0″	.742	58.17	
8″	4′	10″	7″	5/8″	6½″	11′-0″	1/2″	13″	2′-6″	1/2″	13″	5′-3″	1/2″	13″	11′-0″	.786	59.74	
8″	5′	10″	8″	5/8″	6½″	11′-2″	1/2″	13″	2′-8″	1/2″	13″	6′-4″	1/2″	13″	11′-2″	.900	63.90	
8″	6′	10″	8″	5/8″	6½″	11′-2″	1/2″	13″	2′-8″	1/2″	13″	7′-4″	1/2″	13″	11′-2″	.949	65.47	
8″	7′	10″	8″	5/8″	6½″	11′-2″	1/2″	13″	2′-8″	1/2″	13″	8′-4″	1/2″	13″	11′-2″	1.000	68.74	
8″	8′	10″	8″	5/8″	6½″	11′-2″	1/2″	13″	2′-8″	1/2″	13″	9′-4″	1/2″	13″	11′-2″	1.048	70.31	
8″	2′	11″	8″	5/8″	6″	13′-2″	1/2″	12″	3′-0″	1/2″	12″	3′-7″	1/2″	12″	13′-2″	.916	69.31	12′-Span
8″	3′	11″	8″	5/8″	6″	13′-2″	1/2″	12″	3′-0″	1/2″	12″	4′-7″	1/2″	12″	13′-2″	.965	72.71	
8″	4′	11″	8″	5/8″	6″	13′-2″	1/2″	12″	3′-0″	1/2″	12″	5′-7″	1/2″	12″	13′-2″	1.014	74.41	
8″	5′	11″	8″	5/8″	6″	13′-2″	1/2″	12″	3′-0″	1/2″	12″	6′-7″	1/2″	12″	13′-2″	1.063	77.81	
8″	6′	11″	9″	5/8″	6″	13′-4″	1/2″	12″	3′-0″	1/2″	12″	7′-6″	1/2″	12″	13′-4″	1.205	79.94	
8″	7′	11″	9″	5/8″	6″	13′-4″	1/2″	12″	3′-0″	1/2″	12″	8′-6″	1/2″	12″	13′-4″	1.261	83.34	
8″	8′	11″	9″	5/8″	6″	13′-4″	1/2″	12″	3′-0″	1/2″	12″	9′-6″	1/2″	12″	13′-4″	1.316	85.04	
8″	9′	11″	9″	5/8″	6″	13′-4″	1/2″	12″	3′-0″	1/2″	12″	10′-6″	1/2″	12″	13′-4″	1.372	88.44	
8″	10′	11″	9″	5/8″	6″	13′-4″	1/2″	12″	3′-0″	1/2″	12″	11′-6″	1/2″	12″	13′-4″	1.427	90.14	

[1] Depth of fill. [2] Height of Culvert. [3] Thickness of Top. [4] Thickness of Bottom and Sides. NOTE: This table is calculated for a minimum fill of 8 in. of rocks over Culvert slabs and is correct for all fills up to 6 ft. in height.

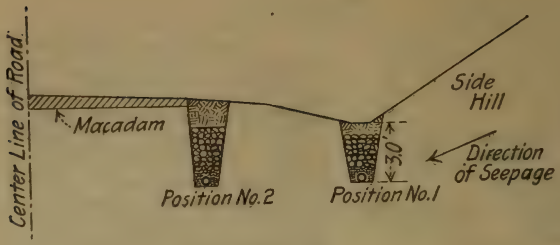


FIG. 14

the hill directly under the stone and the drain is placed as in figure 15, position 1, or two drains are built in position 2. Position 1 is the usual practice, being cheaper and more effective.

The argument for the two side drains is, that in case the throat becomes clogged, a side drain can be taken up without disturbing the macadam. This rarely occurs in a center drain, as it is better protected than those in position 2 and in case the center drain does clog, side drains can be constructed at any time.

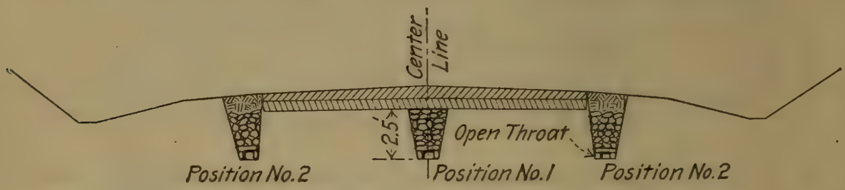


FIG. 15

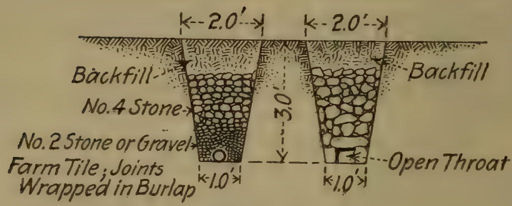


FIG. 16

There are two kinds of drain in general use:

No. 1 is built entirely of stone with an open throat roughly laid as shown; it is satisfactory in a water-bearing strata of gravelly loam or clay, but does not work so well in quicksand, which is liable to fill it up. It is generally cheaper, however, than No. 2.

No. 2 is built of porous farm tile or vitrified tile of a suitable size (usually 3″ to 6″) with open joints, wrapped with a double or triple layer of burlap; the pipe is surrounded and covered with clean gravel or $\frac{3}{4}''$ crushed stone to a depth of 6″, the remaining depth of the trench being filled with large stone. If this drain has a good fall and the outlet is kept free, it will rarely clog even in bad quicksand.

The author has successfully used the following method to prevent

the outlet from clogging: after being brought out from under the macadam, the drain is continued under and across the ditch line, then keeping outside the ditch line, and using a slightly smaller

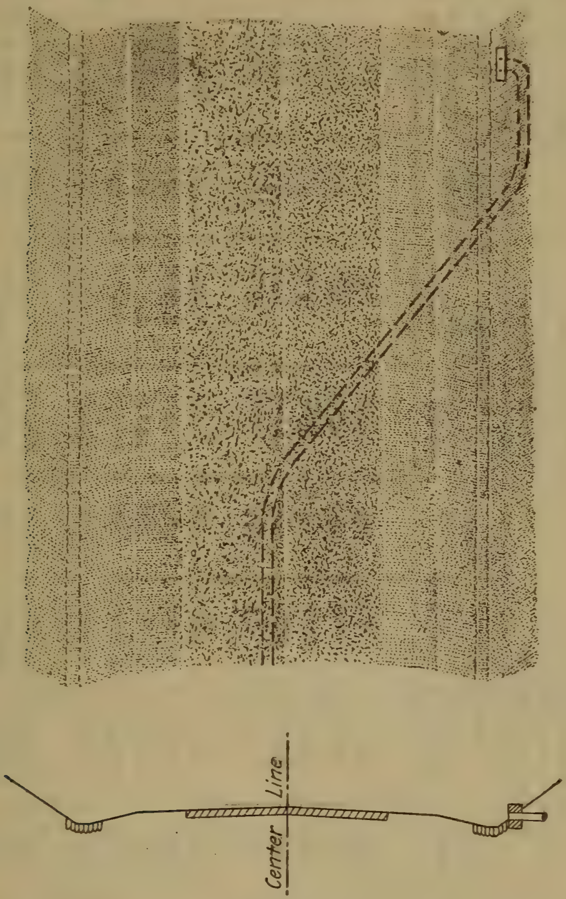


FIG. 17

gradient than that of the open ditch, the tile is continued down the hill until it reaches a point eight or nine inches above the ditch grade. Here it is turned into the open ditch through a small concrete head-wall and what little material it tends to deposit is washed down the ditch by the surface water. (See figure 17.)

In planning the drainage for a road improvement, it is well to make as few changes as possible from the existing scheme. New culverts or a change of direction and amount of water discharged through farm land is almost certain to result in some friction with the owners of the properties affected.

TABLE 14. STANDARD THICKNESS AND WEIGHTS OF CAST-IRON PIPE ADOPTED MAY 12, 1908 BY AMERICAN WATER-WORKS ASSOCIATION

Nominal Inside Diameter Inches	LIGHT 100 Foot Head			MEDIUM 200 Foot Head			HEAVY 300 Foot Head			EXTRA HEAVY 400 Foot Head		
	43 Pounds Pressure			86 Pounds Pressure			130 Pounds Pressure			173 Pounds Pressure		
	Thickness	Weight per Foot	Weight per Length	Thickness	Weight per Foot	Weight per Length	Thickness	Weight per Foot	Weight per Length	Thickness	Weight per Foot	Weight per Length
3	.39	14.5	175	.42	16.2	194	.45	17.1	205	.48	18.0	216
4	.42	20.0	240	.45	21.7	260	.48	23.3	280	.52	25.0	300
6	.44	30.8	370	.48	33.3	400	.51	35.8	430	.55	38.3	460
8	.46	42.9	515	.51	47.5	570	.56	52.1	625	.60	55.8	670
10	.50	57.1	685	.57	63.8	765	.62	70.8	850	.68	76.7	920
12	.54	72.5	870	.62	82.1	985	.68	91.7	1,100	.75	100.0	1,200
14	.57	89.6	1,075	.66	102.5	1,230	.74	116.7	1,400	.82	129.2	1,550
16	.60	108.3	1,300	.70	125.0	1,500	.80	143.8	1,725	.89	158.3	1,900
18	.64	129.2	1,550	.75	150.0	1,800	.87	175.0	2,100	.96	191.7	2,300
20	.67	150.0	1,800	.80	175.0	2,100	.92	208.3	2,500	1.03	229.2	2,750
24	.76	204.2	2,450	.89	233.3	2,800	1.04	279.2	3,350	1.16	306.7	3,680
30	.88	291.7	3,500	1.03	333.3	4,000	1.20	400.0	4,800	1.37	450.0	5,400
36	.99	391.7	4,700	1.15	454.2	5,450	1.36	545.8	6,550	1.58	625.0	7,500
42	1.10	512.5	6,150	1.28	591.7	7,100	1.54	716.7	8,600	1.78	825.0	9,900
48	1.26	666.7	8,000	1.42	750.0	9,000	1.71	908.3	10,900	1.96	1,050.0	12,600

Trade Catalogue Weights

Table [1]

Gauge	Size Mesh	Weight in Pounds per Sq. Ft.
10	$3\frac{1}{2}'' \times 7''$	0.68
12	$3\frac{1}{2}'' \times 7''$	0.54
10	$2\frac{1}{2}'' \times 5''$	0.86
12	$2\frac{1}{2}'' \times 5''$	0.68
14	$2\frac{1}{2}'' \times 5''$	0.48
16	$2\frac{1}{2}'' \times 5''$	0.37
16	$1\frac{1}{2}'' \times 3''$	0.40
16	$1'' \times 2''$	0.50
15	$1'' \times 2''$	0.57
14	$1'' \times 2''$	0.64
13	$1'' \times 2''$	0.78

Table [2]

Mesh	Gauge (Stubs)	Strand Standard or Extra	Section Area per Foot of Width	Weight per Sq. Ft.	Size of Standard Sheets	No. of Sheets in Bundle	No. of Sq. Ft. in 8′ Bundle
$\frac{1}{2}''$	No. 18	Standard	0.209	.74	3′ or 6′ × 8′	5	120
$\frac{3}{4}''$	13	"	0.225	.80	6′ × 8′ or 12′	5	240
$1\frac{1}{2}''$	12	"	0.207	.70	4′ × 8′ or 12′	5	160
2″	12	"	0.166	.56	5′ × 8′ or 12′	5	200
3″	16	"	0.083	.28	6′ × 8′ or 12′	10	480
3″	10	Light	0.148	.50	6′ × 8′ or 12′	5	240
3″	10	Standard	0.178	.60	6′ × 8′ or 12′	5	240
3″	10	Heavy	0.267	.90	4′ × 8′ or 12′	5	160
3″	10	Ex "	0.356	1.20	6′ × 8′ or 12′	3	144
3″	6	Standard	0.400	1.38	5′ × 8′ or 12′	3	120
3″	6	Heavy	0.600	2.07	5′ × 8′ or 12′	3	120
4″	16	Old Style	0.093	.42	$4\frac{1}{2}'$ × 8′ or 9′	6	216
6″	4	Standard	0.245	.84	5′ × 8′ or 12′	5	200
6″	4	Heavy	0.368	1.26	5′ × 8′ or 12′	3	120

Weight and Sectional Area Taken from I. C. S. Handbook

U. S. Standard Gauge	Size Mesh	Sectional Area in Sq. In. per Foot of Width	Weight in Pounds per Sq. Ft.
18	$\frac{1}{2}'' \times 1\frac{1}{2}''$	0.203	0.69
12	$\frac{3}{4}'' \times 2''$	0.253	0.86
12	$1\frac{1}{2}'' \times 3''$	0.188	0.64
16	$2\frac{1}{4}'' \times 6''$	0.087	0.29
16	$3'' \times 8''$	0.130	0.44
16	$3'' \times 8''$	0.059	0.20
12	$3'' \times 8''$	0.109	0.37
10	$3'' \times 8''$	0.162	0.55
10	$3'' \times 8''$	0.243	0.81
10	$3'' \times 8''$	0.324	1.07
7	$3'' \times 8''$	0.400	1.36
4	$6'' \times 12''$	0.245	0.84
4	$6'' \times 12''$	0.368	1.26

NOTE. — Expanded metal for small culverts is generally specified as weighing a certain number of pounds per square foot and having a mesh approximately the size shown on the plans.

[1] Youngstown Expanded Metal

[2] "Steelcrete" Catalogue

TABLE 16. TABLE OF ROUND AND SQUARE BAR WEIGHTS

Round Bars			Plain Square Bars and Twisted Square Bars		
Diameter	Area	Weight	Dimension	Area	Weight
$\frac{1}{4}$	.0491	.167	$\frac{1}{4}$	.0625	.212
$\frac{5}{16}$	.0767	.261	$\frac{5}{16}$	.0977	.332
$\frac{3}{8}$	.1104	.376	$\frac{3}{8}$	.1406	.478
$\frac{7}{16}$	.1503	.511	$\frac{7}{16}$	.1914	.651
$\frac{1}{2}$	.1963	.668	$\frac{1}{2}$	.2500	.850
$\frac{9}{16}$	.2485	.845	$\frac{9}{16}$	.3164	1.076
$\frac{5}{8}$	.3068	1.043	$\frac{5}{8}$	.3906	1.328
$\frac{11}{16}$	.3712	1.262	$\frac{11}{16}$	.4727	1.607
$\frac{3}{4}$	.4418	1.502	$\frac{3}{4}$	.5625	1.913
$\frac{13}{16}$	.5185	1.763	$\frac{13}{16}$	.6602	2.245
$\frac{7}{8}$	.6013	2.044	$\frac{7}{8}$	.7656	2.603
$\frac{15}{16}$	.6903	2.347	$\frac{15}{16}$	.8789	2.988
1	.7854	2.670	1	1.0000	3.400
$1\frac{1}{8}$	.9940	3.380	$1\frac{1}{8}$	1.2656	4.303
$1\frac{1}{4}$	1.2272	4.172	$1\frac{1}{4}$	1.5625	5.313
$1\frac{3}{8}$	1.4849	5.049	$1\frac{3}{8}$	1.8906	6.428
$1\frac{1}{2}$	1.7671	6.008	$1\frac{1}{2}$	2.2500	7.650

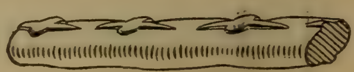
Diameters expressed in inches. Areas expressed in square inches.
Weights expressed in pounds per foot of length.
The twisted square bar is known as the Ransome Bar.

Ransome Bar.

Kahn Cup Bar.

Corrugated Bars.

Diamond Bar.



Thacher Bar.

TABLE 16. *Continued*

Nominal Size of Bar	Weight and Net Sectional Areas of Different Reinforcing Bars									
	Kahn Cup Bar		Twisted Lug Bar		Corrugated Bars		Thacher Bar		Diamond Bar	
	Area	Weight	Area	Weight	Area	Weight	Area	Weight	Area	Weight
$\frac{1}{4}$			0.0625	0.222			0.047	0.16	0.062	0.22
$\frac{3}{8}$	0.1406	0.502	0.1406	0.492			0.100	0.34	0.141	0.48
$\frac{1}{2}$	0.2500	0.893	0.2500	0.870	0.25	0.86	0.18	0.61	0.250	0.85
$\frac{5}{8}$	0.3906	1.394	0.3906	1.350			0.28	0.95	0.391	1.33
$\frac{3}{4}$	0.5625	2.008	0.5625	1.940	0.56	1.93	0.41	1.39	0.563	1.91
$\frac{7}{8}$	0.7656	2.733	0.7656	2.640	0.77	2.65	0.55	1.87	0.766	2.60
1	1.0000	3.570	1.0000	3.450	1.00	3.45	0.71	2.41	1.000	3.40
$1\frac{1}{8}$	1.2656	4.518	1.2656	4.350			0.90	3.06		
$1\frac{1}{4}$	1.5625	5.578	1.5625	5.370	1.56	5.36	1.10	3.74	1.563	5.31

TABLE 17. APPROXIMATE COSTS OF SMALL CONCRETE CULVERTS SIMILAR TO PLATE 6 AND CAST-IRON PIPE CULVERTS

Length Feet	CONCRETE CULVERTS — Size of Opening [1]										CAST-IRON PIPE CULVERTS						
	2′×1.5′	2′×2′	3′×2′	3′×3′	4′×2′	4′×3′	4′×4′	5′×3′	5′×4′	5′×5′	12″ Pipe	14″ Pipe	16″ Pipe	18″ Pipe	20″ Pipe	24″ Pipe	Length Feet
20	$63	$76	$79	$97	$90	$107	$127	$127	$147	$170							20
22	68	81	86	104	97	115	136	137	158	181							22
24	72	86	92	111	104	124	145	146	169	193	$44	$52	$ 61	$ 72	$ 83	$107	24
26	77	91	99	118	111	132	154	156	179	204							26
28	81	96	105	126	118	140	163	166	190	216							28
30	86	101	111	133	126	148	172	175	200	227	52	63	74	88	101	131	30
32	91	106	118	140	133	156	181	185	211	238							32
34	95	111	124	148	140	164	190	194	221	250							34
36	100	118	131	155	147	172	199	204	232	261	61	74	87	104	119	156	36
38	104	121	137	162	154	180	208	214	242	273							38
40	109	126	143	169	162	188	217	223	253	284							40
42	114	131	150	177	169	196	226	233	263	295	69	84	100	120	137	180	42
44	118	136	156	184	176	205	235	243	274	307							44
46	123	141	163	191	183	213	244	253	284	318							46
48	127	146	169	199	190	221	253	262	295	330	78	95	114	135	156	205	48
50	132	151	175	206	198	229	262	272	305	341							50
Cost per ft.	$2.30	$2.50	$3.20	$3.63	$3.60	$4.06	$4.50	$4.83	$5.27	$5.70	$1.45	$1.80	$2.18	$2.62	$3.06	$4.07	

Note: — These approximate costs figured on a basis of $8.00 per cu. yd. for Concrete Decks and Parapets; $6.00 per cu. yd. for Concrete Bottoms, sides, and wings; 10 cts. per sq. ft. for Expanded Metal in place. Medium weight Cast-Iron Pipe figured at $35.00 per ton in place. $9.00 per cu. yd. for Headwalls. See page 300 for quantities of 2d and 3d cl. concrete.

[1] Span is noted 1st, that is a 3′ × 2′ Culvert means Span 3′ Height 2′.

TABLE 18. PROPERTIES OF CAMBRIA STANDARD I-BEAMS

Depth of Beam	Weight per Foot	Area of Section	Thickness of Web	Width of Flange	For Fiber Stress of 12,500 lbs. per Sq. In. for Bridges
Inches	Pounds	Sq. Inches	Inch	Inches	Coefficient of Strength
3	5.50	1.63	.17	2.33	13,790
3	6.50	1.91	.26	2.42	14,950
3	7.50	2.21	.36	2.52	16,180
4	7.50	2.21	.19	2.66	24,850
4	8.50	2.50	.26	2.73	26,480
4	9.50	2.79	.34	2.81	28,110
4	10.50	3.09	.41	2.88	29,750
5	9.75	2.87	.21	3.00	40,300
5	12.25	3.60	.36	3.15	45,390
5	14.75	4.34	.50	3.29	50,490
6	12.25	3.61	.23	3.33	60,520
6	14.75	4.34	.35	3.45	66,610
6	17.25	5.07	.47	3.57	72,740
7	15.00	4.42	.25	3.66	86,260
7	17.50	5.15	.35	3.76	93,290
7	20.00	5.88	.46	3.87	100,430
8	18.00	5.33	.27	4.00	118,490
8	20.25	5.96	.35	4.08	125,400
8	22.75	6.69	.44	4.17	133,570
8	25.25	7.43	.53	4.26	141,740
9	21.00	6.31	.29	4.33	157,260
9	25.00	7.35	.41	4.45	170,260
9	30.00	8.82	.57	4.61	188,640
9	35.00	10.29	.73	4.77	207,020
10	25.00	7.37	.31	4.66	203,500
10	30.00	8.82	.45	4.80	223,630
10	35.00	10.29	.60	4.95	244,050
10	40.00	11.76	.75	5.10	264,480
12	31.50	9.26	.35	5.00	299,740
12	35.00	10.29	.44	5.09	317,030
12	40.00	11.76	.56	5.21	341,540

TABLE 18. *Continued*

Depth of Beam	Weight per Foot	Area of Section	Thickness of Web	Width of Flange	For Fiber Stress of 12,500 lbs. per Sq. In. for Bridges
Inches	Pounds	Sq. Inches	Inch	Inches	Coefficient of Strength
15	42.00	12.48	.41	5.50	490,840
15	45.00	13.24	.46	5.55	506,490
15	50.00	14.71	.56	5.65	537,130
15	55.00	16.18	.66	5.75	567,770
15	60.00	17.65	.75	5.84	598,410
18	55.00	15.93	.46	6.00	736,620
18	60.00	17.65	.56	6.10	779,440
18	65.00	19.12	.64	6.18	816,200
18	70.00	20.59	.72	6.26	852,970
20	65.00	19.08	.50	6.25	974,600
20	70.00	20.59	.58	6.33	1,016,490
20	75.00	22.06	.65	6.40	1,057,340
24	80.00	23.32	.50	7.00	1,449,460
24	85.00	25.00	.57	7.07	1,505,430
24	90.00	26.47	.63	7.13	1,554,450
24	95.00	27.94	.69	7.19	1,603,470
24	100.00	29.41	.75	7.25	1,652,490

Explanation of the coefficient of strength in the above table and examples showing use in practice.

The coefficient of strength for each sized beam represents the maximum uniformly distributed load, in pounds, that will produce a fiber stress not exceeding 12,500 lbs. per sq. inch multiplied by the span in feet.

If the load to be investigated is a concentrated load it must be changed to an equivalent uniform load in order to use the values given. This is done by multiplying the concentrated load by 2.

EXAMPLE: Suppose that it is required to determine the size I-beam that will carry a 40,000 lb. load in the center of a 15′ span and a uniformly distributed load of 20,000 lbs. The coefficient of resistance for the concentrated load will be 2 (40,000) × 15 = 1200000

Uniform load 20,000 × 15 = 300000

1500000

The required beam must have a coefficient of resistance of 1500000 plus the coefficient due to its own weight. A 24″ beam weighing 90 lbs. per foot has a coefficient of 1,554,450.

The beam weighs 90 × 15 = 1,350. The coefficient for the beam weight is 1,350 × 15 = 20,250, which deducted from 1,554,450 gives a coefficient of 1,534,200, which is slightly greater than required and is safe.

CHAPTER IV

FOUNDATIONS FOR BROKEN STONE ROADS

CONCRETE foundations are considered under Brick Pavements in chapter V.

The real foundation of a road is the earth subgrade; generally, however, the term foundation is used in speaking of the lower course of stone, gravel, etc., used to distribute the concentrated wheel loads. A discussion can be developed under the following heads:

1. The bearing power of different soils.
2. The concentrated wheel loads on improved roads.
3. The distributing action of foundation courses and the depth required for different soils.
4. The different kinds of foundation courses.
5. The distribution of the stone in the foundations.
6. Special cases.

1. Bearing Power of Soils

The subgrade develops its greatest bearing power when dry. In the following discussion we assume that the soils are protected by a well-designed drainage system.

Mr. W. E. McClintock, Mem. Amer. Soc. C. E., Chairman of the Massachusetts Highway Commission, published in the 1901 report of that Commission a valuable statement of the results of their investigations on the bearing power of soils and the distribution of wheel loads by the macadam. The conclusions have been well tested in practice and found to be satisfactory.

"The Commission has estimated that non-porous soils drained of ground water, at their worst will support a load of about 4 lb. per square inch; and having in mind these figures the thickness of broken stone has been adjusted to the traffic.

"On a road built of fragments of broken stone the downward pressure takes a line at an angle of 45 degrees from the horizontal and is distributed over an area equal to the square of twice the depth of the broken stone. If a division of the load in pounds at any one point by the square of twice the depth of the stone in inches gives a quotient of four or less, then will the road foundation be safe at all seasons of the year. On sand or gravel the pressure can be safely put at twenty pounds per square inch. . . .

"Acting on this theory the thickness of the stone varies from four inches to sixteen inches, the lesser thickness being placed over good gravel or sand, the greater over heavy clay, and varying thicknesses on other soils. In cases where the surfacing of broken stone exceeds six inches in thickness, the excess in the base may be broken stone, stony gravel or ledge stone; the material used for the excess depending entirely upon the cost, either being equally effective."

2. Concentrated Wheel Loads

There should be some limit placed by law to the maximum load per lineal inch of tire for vehicle using improved roads. The roads can then be designed for this load with no danger of failure from unreasonable pressures. Road work is handicapped in this country by the lack of wide tire statutes and the regulation of traction engines using sharp lugs on the wheels. At present it is necessary to assume a loading that will probably not be exceeded by the unregulated traffic. Many engineers favor a law limiting the load on improved roads to 700 to 800 lb., to the lineal inch, which is a reasonable limit; with a six inch thread this would mean a load of nine tons for a four wheel truck provided the load was uniformly distributed. This is beyond the limits of team hauling.

Most of the mechanical trucks in present use have tires wide enough to reduce the pressure below this limit. Near some of the large cities, however, mechanical trucking has increased to proportions that amount to a regular freight line and excessive loads are carried; the load and speed for such trucks must be regulated, for no road can stand abuse of this character.

The following regulations governing the control of motor trucks and traction-engines were prepared by the New York State Highway Commissioner to go into effect in 1914.

Regulations for State and County Highways Adopted by the Commissioner of Highways of the State of New York

Sec. 1. No traction-engine, road-engine, hauling-engine, trailer, steam-roller, automobile truck, motor or other power vehicle shall be operated upon or over the state or county highways, the face of the wheels of which vehicle are fitted with flanges, ribs, clamps, cleats, lugs or spikes. This regulation applies to all rings or flanges upon guiding or steering wheels of any such vehicle. In case of traction-engines, road-engines or hauling-engines which are equipped or provided with flanges, ribs, clamps, cleats, rings or lugs, such vehicles shall be permitted to pass over said highways provided that cleats are fastened upon all the wheels of such vehicles, and are not less than $2\frac{1}{2}$ in. wide and not more than $1\frac{1}{2}$ in. high, and so placed that not less than two cleats on each wheel shall touch the ground at all times, and the weight shall be the same on all parts of said cleats.

Sec. 2. No traction-engine, trailer, steam-roller, automobile truck, motor or other power vehicle shall be operated upon or over the state or county highways; nor shall any object be moved over or upon any such highways upon wheels, rollers or otherwise, in excess of a total weight of 14 tons, including the vehicle, object or contrivance and load, without first obtaining the permission of the State Commission of Highways as hereinafter provided. No weight in excess of 8 tons shall be carried on any one axle of any such vehicle.

Sec. 3. The tire of each wheel of a traction-engine, road-engine, hauling-engine, trailer, steam-roller, automobile truck, motor or other power vehicle (except traction-engines, road-engines, and hauling-engines) shall be smooth, and the weight of such vehicle, including load, shall not exceed 800 lb. upon any inch in width of the

tire, wheel, roller or other object, and any weight in excess of 800 lb. upon an inch of tire is prohibited unless permission is obtained from the State Commissioner of Highways as hereinafter provided.

SEC. 4. No motor or other power vehicle operated upon any state or county highway shall be of a greater width than 90 in., except traction-engines which may have a width of 110 in.

SEC. 5. No traction-engine, road-engine, hauling-engine, trailer, steam-roller, automobile truck, motor or other power vehicle, carrying a weight in excess of 4 tons, including the vehicle, shall be operated upon any state or county highway at a speed greater than 15 mi. per hr.; and no such vehicle carrying a weight in excess of 6 tons, including the vehicle, shall be operated upon any such highway at a speed greater than 6 mi. per hr. when such vehicle is equipped with iron or steel tires, nor, a speed greater than 12 mi per hr. when the vehicle is equipped with tires of hard rubber or other similar substance.

SEC. 6. The State Commisssioner of Highways, upon proper application in writing, may grant permission for the moving of heavy vehicles, loads, objects or structures in excess of a total weight of 14 tons over state and county highways, upon proper application in writing being made therefor, and under such restrictions as the Commissioner may prescribe.

SEC. 7. The owner, driver, operator or mover of any vehicle over any state or county highway shall be responsible for all damages which said highway may sustain as a result of a violation of any of the provisions of the foregoing Rules and Regulations, and the amount thereof may be recovered in an action of tort by the State Commissioner of Highways or by any County Superintendent of Highways of any county or by any Town Superintendent of Highways of any town in which said violation occurs.

[1] SEC. 8. These regulations take effect October 20, 1913.

"Section 24 of Chapter 25 of the Consolidated Laws entitled 'The Highway Law' provides that any disobedience of any of the foregoing rules and regulations shall be punishable by a fine of not less than $10 and not more than $100 to be prosecuted by the Town, County or District Superintendent, and paid to the County Treasurer to the credit of the fund for the maintenance of such highways in the town where such fine is collected."

Under these regulations properly enforced any of the ordinary foundation courses can be successfully used except on the heaviest traffic roads (see Classification page 74) provided the depth is varied to meet the soil conditions.

Heavily loaded farm wagons exert a pressure of about 350 lb., per lineal inch of tire width as determined from the records of produce dealers in Western New York, and the author believes that a road designed to distribute a 4,200-pound wheel load on a six-inch tire would be safe.

NOTE: — The length of wheel bearing on a well-constructed macadam road is about 1″.

The use of this loading and the application of the rules for distribution of pressure given by Mr. McClintock in the preceding quota-

[1] This provision for enforcement does not work well; enforcement should be in the hands of the State authorities.

tion results in a depth of 15″ for heavy clay or a fine sandy loam, and a depth of 5″ for gravel, which check his results.

The thickness to be used in the intermediate cases must depend on the judgment of the engineer. The following examples are intended only as a guide for the more common cases. The amount for special cases often depends on trial.

Sand and gravel require from 4″ to 6″; New York State uses 7″ as a minimum where motor trucking is expected; Massachusetts uses the following section on good gravel.

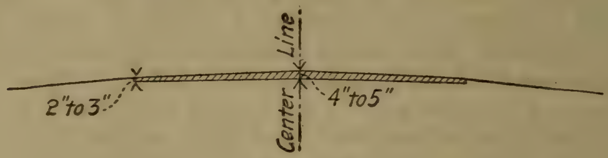


FIG. 18

Wherever the total depth is less than 5″ the stone should be laid in one course and classified as top stone.

For a light clay loam an average depth of 7″ to 9″ is sufficient in cut; for fills over 2′ deep 7″ is enough; high fills even of clay after having once settled rarely give trouble with 7″ of stone.

Heavy clay requires at least 12″ in cut; if the soil is springy and especially hard to drain, 15″ to 18″ is advisable.

For shallow fills (see figure 19):

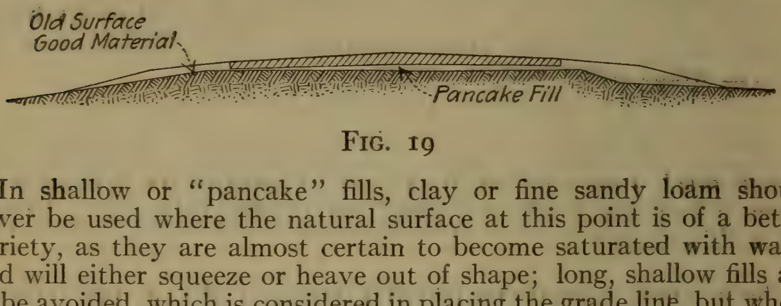


FIG. 19

In shallow or "pancake" fills, clay or fine sandy loam should never be used where the natural surface at this point is of a better variety, as they are almost certain to become saturated with water and will either squeeze or heave out of shape; long, shallow fills are to be avoided, which is considered in placing the grade line, but where unavoidable, the best available material should be obtained and the original surface well broken up to form a bond with the new fill. Where clay is used, it should be treated as in cut. For fills of intermediate depths [1′ to 2′] 8″ to 9″ is satisfactory.

A fine sandy loam is difficult to drain because of its strong capillary action. Mr. Charles Mills, Chief Engineer of the Massachusetts Highway Commission, in the report for the year 1902 states that a loam of which 30% or more will pass a 100 sieve will require from 10″ to 15″ of stone.

To illustrate the different stone depths that may be used in a short distance, an extract follows from the construction report on foundations for "Clover Street, Section 1," a road near Rochester, N.Y. This was built in 1907–1908 and has held satisfactorily under farm traffic.

Clover Street Road, Section 1

The normal depth of stone on this road was 7″ $\left.\right\}$ 3″ Top, 4″ Bottom

Station to Station		Character of Subgrade	Total Depth of Stone
180	183 + 25	Cut in sand and gravel	6″
183 + 25	186 + 25	Clay fill	8″
186 + 25	187	Clay cut	11″
187	190	Sand, gravel and clay	7″
190	191	Clay cut	12″
191	193	Clay loam fill	7″
193	200	Sand and gravel	6″

PREPARATION OF SUBGRADE

It is evident from the pressures to which a road is subjected that the subgrade must be well consolidated before placing the foundation stone. This is usually effected by rolling with a 10 or 15 ton steam roller, exerting a pressure of 350 to 500 pounds per linear inch of wheel width, and is continued until the grade is firm and compact.

The difficulties of consolidation in different soils and the methods of overcoming them will be included in chapter XI.

KINDS OF FOUNDATION COURSES

The foundation courses in ordinary use are as follows:

1. Crushed stone
2. Screened gravel
3. Field stone sub-base
4. Pit gravel sub-base
5. Field stone-sub base bottom course
6. Pit gravel sub base-bottom course
7. Quarry stone base or Telford.

1. Broken Stone Bottom Course.

This style of construction is the one in most general use. Where local stone is abundant and well distributed, such a course will cost from $2.00 to $2.50 per cubic yard rolled in place; where imported stone is necessary, the cost depends largely upon the freight rate and the length of haul and may run as high as $5.00. Bottom of this kind is generally used where the total depth of stone metaling does not exceed 6″ to 8″ after rolling. Beyond these depths it is often cheaper to substitute sub-base or sub-base bottom course for a part or the whole of the broken stone course.

The method of construction by the New York State Highway Commission is shown in the following extract from their 1911 specifications:

Stone Macadam Bottom Course

"After the subgrade has been prepared and has been accepted by the Engineer, a layer of broken stone of the approved size and quality for bottom course shall be spread evenly over it to such a depth that it shall have, when rolled, the required thickness. The depth of the loose stone shall be gauged by laying upon the subgrade cubical blocks of wood of the proper size and spreading the stone evenly to conform to them."

"The roller shall be run along the edge of the stone backward and forward several times on each side before rolling the center. Before putting on the filler the course shall be rolled until the stone does not creep or weave ahead of the roller. In no case shall the screenings or sand for filler be dumped in mass upon the crushed stone, but they shall be spread uniformly over the surface from wagons or from piles that have been placed on the shoulders. It shall then be swept in with rattan or steel brooms and rolled dry. This process shall be continued until no more will go in dry, when the surface shall, if required by the Engineer, be sprinkled to more effectually fill the voids. No filler shall be left on the surface, and surface of bottom course stone shall be swept clean before covering with top course. Only such teaming as is necessary for distributing the materials will be allowed on the bottom course. Any irregularities or depressions, the result of settlement, rolling or teaming, if slight, shall be made good with broken stone of the same size used in the bottom course, otherwise the stone shall be removed and the subgrade regraded and rolled. Such removal and restoring of the surface shall be made at the expense of the Contractor. Screenings shall not be used in leveling up irregularities or depressions."

Massachusetts uses no filler; otherwise their construction is substantially the same as New York.

Where imported stone is specified or the local stone is suitable for both top and bottom courses, the size used for bottom course is known commercially as "No. 4 stone" and ranges from $2\frac{3}{4}''$ to $3\frac{3}{4}''$ in its greatest dimension; the smaller sizes are used for the top course, for concrete and for filler; where the local material is only fit for bottom, the course is made up of stone ranging from $1''$ to $3\frac{3}{4}''$ in order to use up the total output of the crusher. The stone smaller than $1''$ is used for filler, on the shoulders, and sometimes for the cheaper grades of concrete. In specifying the sized stone for a particular job, economy is considered. Stone sized from $1''$ to $3\frac{3}{4}''$ is perfectly satisfactory. The only reason for limiting the usual size from $2\frac{3}{4}''$ to $3\frac{3}{4}''$ is that it leaves the $1''$ to $2\frac{3}{4}''$ stone for the top course; a uniform grade is important for the top and the size mentioned gives a smooth finish.

The ratio of loose depth to rolled depth is given on page 272.

Where filler is not used in the construction of the bottom course more binder is required for the top; it is our opinion that the use of filler is the better construction.

The clause concerning teaming in the quoted specifications is a dead letter; teaming helps to consolidate the bottom provided it is

distributed over the full width and care is taken in watching the course to prevent loss of shape when the traffic is first turned on or after a long continued rainfall.

2. Gravel Bottom Course.

Screened gravel 1″ to 3½″ in size is used in place of crushed stone; the course is constructed in the same manner as described above, except that a filler containing some clay or clay loam is preferable to a coarse sand, and it is often necessary to wet the course in order to consolidate it satisfactorily.

A gravel bottom should be made somewhat thicker than a crushed stone bottom as the fragments do not interlock as firmly as crushed stone.

The choice between a screened gravel or crushed stone bottom depends entirely on the relative cost. Under favorable conditions a screened gravel bottom course will cost from $1.30 to $2.00 per cubic yard, rolled in place.

3. Field Stone Sub-base.

Field stone sub-base is constructed, as shown in the cut, of field boulders roughly placed and filled with gravel, waste No. 2 stone or stone chips; no attempt is made to finish the top of the course exactly to line and grade, as any small inequalities can be filled with bottom stone. The depth varies from 5″ to 12″ depending on the soil encountered in the size of the available field stone. In designing a bottom course of this kind, care must be taken to have accurate data as to the average size of stone available. If the demands of a foundation were fully satisfied by a 5″ sub-base course, it might still be more economical to use a 7″ course if the stone averaged seven inches, because the extra work of sorting and sledging to a 5″ size would result in a higher cost per square yard than for a 7″ depth.

FIG. 20

The amount of stone and filler required per cubic yard in place is given on page 272.

Under favorable conditions this sub-base can be constructed for $1.00 to $1.50 per cubic yard.

4. Pit Gravel or Creek Gravel Sub-base.

Stony gravel is a satisfactory material for sub-base; it can be readily constructed for any depth from 2″ to 24″ if required, and where a pit or creek bar is near, the cost of such a course should run from $0.80 to $1.25 per cubic yd.

The ratio of loose to consolidated gravel for such a course is given on page 272.

5. Field Stone Sub-base Bottom Course.

Sub-base bottom course is essentially the same construction as sub-base, except that, as the top course is placed directly upon it, the stone must be more carefully assorted as to size, more carefully placed as to line and grade, and a better grade of filler must be used.

Crushed stone (crusher run) or coarse gravel make a satisfactory filler.

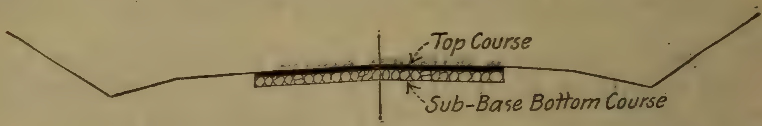


FIG. 21

The course can be of any depth from 5″ up, depending, as for sub-base, on the soil and average size of stone; it is practically impossible to make a large stone bottom of this kind conform exactly to line and grade; a variation of 1″ either above or below grade is usually allowed and the inequalities taken out with the top stone; this requires that the top course must be at least 3″ deep after rolling.

Sub-base bottom is especially applicable for long stretches of road requiring a depth of 9″ to 12″; it usually costs from $1.30 to $1.70 per cubic yard in place where fence stone is available, and by its use the item of higher-priced bottom stone is reduced. However, on a hard foundation it is generally better to use 4″ to 5″ of ordinary broken stone bottom course instead of the sub-base bottom course even if more expensive, because the small stone construction is more uniform in its resistance to heavy loads and the top course will wear more evenly and longer.

An extract from the 1915 New York State Specifications is given below.

Sub-base Bottom Course

When field or quarry stone is used for constructing the foundation course it shall be of a hard, sound and durable quality, acceptable to the Engineer; the stones shall be placed by hand so as to bring them in as close contact as possible. When quarry stones are used they shall be placed on edge. The depth of the stone shall in no case be greater than the depth specified for the course, the width shall not be greater than the depth, nor more than six inches; and the length shall not be greater than one and one-half times the depth, nor more than 12 inches. The distribution of the stone shall be of a uniformity satisfactory to the Engineer. The long dimension shall always be placed crosswise the road. After laying, this course shall be thoroughly rolled with an approved roller weighing not less than 10 tons, and shall then be filled with stone or coarse gravel as directed and again rolled until the stones are bound together and thoroughly

compacted; but no gravel shall be used for filling except under written permission of the Engineer. All holes or depressions found in rolling shall be filled with material of the same quality and the surface shall be rerolled until it conforms to the lines and grades shown on the plans. When field stone is used approved tailings may be used for filling. In all cases a sufficient amount of fine material shall be used to fill all voids. In limited areas where the use of a roller is impracticable heavy tampers may be used to consolidate the material.

6. Pit Gravel Bottom or Sub-Base Bottom.

A stony gravel containing not over 15% of loam makes a satisfactory course; the depths vary from 4″ to 18″; pit or creek gravel even when unusually coarse has from 40 to 60% of fine material; a suitable gravel for pit run bottom should not contain more fine material passing a $\frac{1}{4}''$ screen than coarse material retained on a $\frac{1}{4}''$ screen. If there is a large excess of fine the gravel should be screened and remixed at the bin in proper proportions.

The great difficulty in this construction is to get proper consolidation without too much delay. It is advisable to lay a course of this kind at least two weeks ahead of the top stone in order to give traffic and rains a chance to help consolidate the course. The addition of 10% of loam to clean gravel will quicken the consolidation. This can be done either at the pit by leaving a thin layer of loam when stripping which runs down with the gravel in loading or by placing from $\frac{1}{2}''$ to 1″ of loam on top of the gravel as spread on the road; the author has succeeded in getting rapid consolidation by snatching loaded teams over the loose course with the road roller; the roller continually smooths out the gravel and eases the haul for the teams; the horses' hoofs and wagon wheels punch into the gravel and pack it down rapidly. Sprinkling helps. A gravel bottom consolidates unevenly and it is always necessary to reshape it somewhat after consolidation; about $0.05 per cu. yd. should be allowed for this reshaping of crown and elimination of humps and hollows. A properly consolidated gravel bottom will permit a 4-ton load on $3\frac{1}{2}''$ tires passing over it without making a wheel mark over $\frac{1}{8}''$ deep; this is a simple available construction test. We have gone into some detail covering this construction as it is the most economical type of bottom in a large number of cases but is not generally favored because it is harder to consolidate than the other types of bottom. With a 3″ or preferably a 4″ madacam top it has proved perfectly satisfactory on all but the heaviest traffic roads.

The cost of a gravel bottom ranges from $0.80 to $1.50 per cu. yd. in place provided the hauls are short.

The depths of gravel is gauged by blocks or lines and the ratio of loose to rolled depth is approx. 1.2 (see page 272).

7. Telford Base.

Telford base is rapidly going out of use in the United States because of the difficulty of maintaining a top course laid upon it. It seems

to be too rigid and is more expensive than sub-base or sub-base bottom course, costing about $1.80 to $2.00 per cubic yard under favorable conditions.

A good description of a telford construction is given by Mr. William Pierson Judson in "Roads and Pavements." The following quotation is an extract from his book:

"On this subgrade are then placed by hand the stones forming the telford foundation, which may vary in size as shown below: each stone must be set vertically upon its broadest edge, lengthwise across the road and forming courses and breaking joints with the next course, so as to form a close and firm pavement. The stones are then bound by inserting and driving stones of proper size and shape to wedge the stones in their proper position. All projecting points are then broken with a sledge or hammer so that no projections shall be within four inches of the finished grade line.

"The telford foundation is then rolled with a steam roller of ten or more tons weight, until all stones are firmly bedded and none move under the roller. All depressions are then filled with stone chips not larger than two and one-half inches, and the whole left true and even and four inches below the line of finished grade and cross-section.

"A good workman will average about twenty minutes in setting a square yard of this telford foundation, which may be formed of any kind of quarried rock which is most available: cobble-stones are not suitable.

"The practice in 1901 in the states named is here shown:"

TABLE 19. SIZES OF STONE FOR TELFORD FOUNDATION, IN INCHES

State	Depth, as set on Edge		Width, as set		Length set across Road		Remarks
	Max.	Min.	Max.	Min.	Max.	Min.	
New Jersey .	8	8	4	—	10	—	Alternate end-stones double length.
Mass.	6	5	10	4	15	6	Two inches gravel rolled on subgrade as base.
Conn.	8	8	10	6	18	8	Macadam covering formed in one layer.
New York ..	8	6	10	4	15	6	Used only on unstable ground as foundation for macadam.

Distribution of Stone in Foundations.

In the discussion of sections, Table 9 shows that most of the traffic keeps to the middle 10 or 12 feet; to make a consistent design the foundation should therefore be thicker in the middle than on the sides for the ordinary crushed stone bottom, and where sub-base is required it is often unnecessary to place it the full width of the metaling.

Figure 22 is an example of such a foundation course for ordinary soils as used by the New York State Highway Commission in 1910.

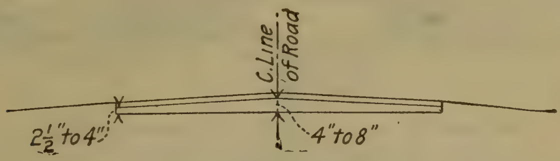


FIG. 22

Figure 23 is an example of an economical sub-base for a light traffic road as used by the Illinois Highway Commission in 1910.

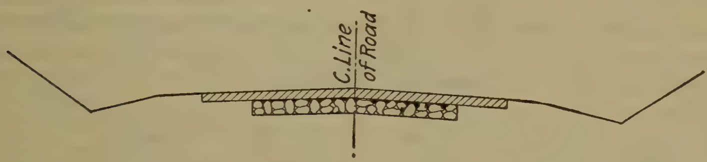


FIG. 23

On a heavy traffic road, however, the writer does not believe that the width of sub-base should be less than the width of metaling.

Special Cases.

Long stretches of comparatively level ledge rock, peat, muck, and vegetable loam may be placed under this head.

Where a road is on the surface of ledge rock for any distance, the usual cross-section of part cut and part fill cannot be used because of the high cost of shallow rock excavation for ditches; the grade should be lifted to make the normal section fill and the best available material (not clay) used in its construction. Where conditions of this kind prevail, dirt is usually hard to obtain and often a stone fill is cheaper and also more satisfactory.

The construction shown below was used for a stretch of two and one-half miles on the Leroy-Caledonia State Highway in New York, where ledge rock was encountered as described.

The price for the stone fill was $1.23 per cubic yard in place constructed as shown; the road was built in 1910 and has given satisfaction; such a base, however, is very rigid, which will probably cause a more rapid deterioration of the top course than if earth were used; the minimum thickness of top for such a fill is 3″ as it is impossible to construct it exactly to line and grade; it was found that by allowing a variation of 1″ either above or below the grade elevation, the fill could be readily constructed, and these small inequalities were taken out with the top stone. A top course having such a variable thickness should be paid for by weight and not by volume in place. (See page 268, Cost Data.)

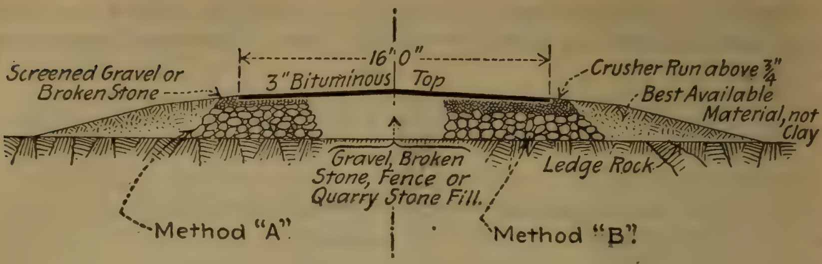


FIG. 24

Fill can be made of fence stone, gravel, quarry spalls, stone chips, or run of crusher stone over $\frac{3}{4}''$ in size.

METHOD A. — Boulders up to 2 cu. ft. can be used, placing the largest in the bottom of the fill; the top layer must be fairly uniform and not over 8″ in size and must be roughly placed by hand to reduce the voids as much as possible, provided this layer of large stone is within 4″ of the bottom of the top course. The top 8″ to be filled with stone chips or gravel and a cushion of at least 2″ of screened gravel, stone chips or crusher run of broken stone over $\frac{3}{4}''$ in size to be placed on top to bring the fill to the correct grade and crown for the top course.

METHOD B. — Same materials and manipulation as Method A, except that provided the top of the boulder fill is more than 4″ from the bottom of the top course the top layer of the boulder fill need not be placed by hand. (See sketch, Method B.)

Peat, Muck, Vegetable Loam, or Silt.

Where the material is semifluid the only solution is a pile and grillage foundation.

Swamps, as ordinarily encountered, can be treated successfully by using a corduroy or mattress foundation covered with a deep fill of gravel or large stone. In some cases where the muck is comparatively stiff, a gravel or boulder fill alone will give a satisfactory foundation.

Where swamps are crossed by improved roads, the location usually follows the old road which has often been corduroyed in the past; in such a case the old foundation should not be disturbed; a sufficient additional depth of stone can be added to keep the shape of the section intact.

As an example, the Scottsville-Mumford New York State improvement crossed a 1000 ft. stretch of muck on the old road location; it was found that the original cedar corduroy was in good shape; an 18″ depth of large boulders was placed on the old foundation and surfaced with 6″ of broken stone macadam. This stretch of road has kept its shape and has not settled; it affords a good example of the statement made on page 61, that in many special cases the depth of the stone is determined by trial; the boulders were

put on in successive layers of 6″ each until there was no material movement under the roller and then surfaced with the broken stone macadam.

Under a heavy load the whole road-bed will vibrate for 100 feet, but the shape remains intact.

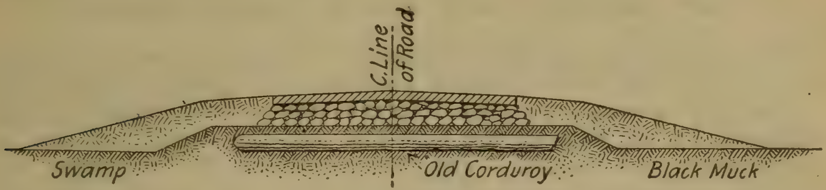


FIG. 25

Economical Foundation Design Macadam Roads

The economical design of foundation courses may be summarized as follows.

For moderate traffic use pit run coarse local gravel if available varying the depths to suit the soil. If gravel is not available use a macadam bottom for ordinary soils and field stone sub-base or sub-base bottom for bad foundations. The economy in the design of macadam roads is greatly increased by utilizing local material, preferably uncrushed, to its fullest extent. We wish to emphasize this point (see design report page 210). If the supply of local material is limited it should be used for as much of the road as possible and advantage should be taken of the different local supplies by changing the design to allow their use with short hauls.

Uniform designs which disregard limited amounts of local materials often raise the cost from $500 to $1,000 per mile.

Conclusions.

In the design of a road, the amount of material required for the foundation courses can be only approximated. This is the only item in the preliminary estimate that cannot be figured within definite limits. It can be closely estimated if careful data on the soils is obtained from local people and from the preliminary survey (see page 151), but a certain leeway must be given the constructing engineer so that he may vary the estimated depths to meet the construction conditions and build a consistent road.

CHAPTER V

TOP COURSES AND THEIR MAINTENANCE

The selection of the most economical top course that is suitable for a given road is the hardest problem of Highway Engineering.

The relative economy of the different constructions is theoretically expressed by the sum of the first cost and the capitalized cost of maintenance and renewal. The first can be readily estimated, but the cost of maintenance and renewal cannot be figured with any degree of accuracy for single special cases, and even on large systems it can only be approximated because of the new factor of motor vehicle traffic. The life of any surfacing is comparatively short, a fact generally overlooked in most of the popular literature on Good Roads.

On any road the amount and class of traffic will fluctuate, and roads that are designed for light travel will often fail under temporary heavy traffic which, for some reason, is diverted from its normal course. The first improved roads built in any locality will for a time carry more than their share of the traffic, which is naturally reduced by the subsequent construction of adjacent improvements. It can be readily seen that it is difficult to judge the amount of traffic a road will handle and that a short-time traffic estimate is valueless as a basis for a definite conclusion.

The design of the top course is usually based on a comparison of the actions of different kinds of previously improved roads that serve districts similar to that under consideration. Roads may be divided into four general traffic classes.

Class I. Main trunk roads, for 5 to 20 miles out of cities of say 50,000 and upwards and in the business sections of villages, which carry the concentrated farm and truck garden traffic of a large area and are subjected to continuous auto truck and touring car traffic.

Class II. Main through automobile routes, at greater distances from the cities, which have a large touring car traffic and medium heavy farm produce traffic.

Class III. Secondary or feeder roads and cross roads having a medium heavy farm produce traffic and light auto traffic.

Class IV. Pleasure roads or scenic routes that have a heavy touring car and light steel tire traffic.

This chapter describes the advantages and disadvantages of the various types and in the discussion of maintenance indicates in a general way their economic limitations.

Waterbound Macadam

Waterbound macadam is constructed of crushed fragments of suitable rock, filled with rock dust and sprinkled and rolled until firm and hard. The cost varies from about $3.50 per cubic yard

where local materials are available to \$6.00 where the stone is imported and the haul is long. A fair average price for roads in Western New York would be \$4.30 per cubic yard, or 35¢ per square yard for a three-inch depth.

Depth of Course.

As the top stone is relatively more expensive than the bottom course a good design calls for the least thickness of top which can be successfully constructed and maintained.

In 1901 the thickness used for top-course macadam in Massachusetts, New York, Connecticut, and New Jersey was 2″, and the size of the top-course stone fragments ranged from ½″ to 1½″ in Massachusetts to 1″ to 2″ in New York. Experience demonstrated that with a course as thin as 2″, the larger stone fragments tended to "kick out" under traffic and that the top wore out by raveling rather than by the abrasive action of the teaming. For this reason the best practice at present calls for a 3″ depth of finished top course, using stone ranging in size from 1¼″ to 2¾″; this depth makes it possible for the large stone fragments to interlock more firmly than in a 2″ course.

Crowns.

The crowns used on plain macadam are ½″ to 1′ to ¾″ to 1′; while ½″ to 1′ is satisfactory when first built, the gradual loss of crown due to traffic and weather action soon makes it too flat to shed the water. Mr. Charles Mills, Chief Engineer of the Massachusetts Highway Commission, reports the following loss of crown on State roads in Massachusetts and concludes that an original crown of ¾″ to 1′ is advisable, except in villages where the traffic is in two lines. A ⅝″ to 1′ crown has proved satisfactory in New York State.

TABLE 20. TESTS MADE IN DECEMBER, 1901

Date of Original Construction	Number of Tests	Original Crown (Inches per Foot)	Present Crown (Inches per Foot)
1895	7	0.694	0.500
1896	9	0.583	0.514
1897	12	0.645	0.500
1898	7	0.625	0.500
1899	2	0.688	0.625

From the Massachusetts Highway Report for 1901.

Maximum Grades.

Waterbound macadam gives a good footing for horses on the steepest grades that are ever constructed; the limit of grade for this construction is determined by the cost of maintenance; on steep grades macadam washes badly and the cost of maintenance is high. Good practice limits its use to grades of 5% or under, although

it has been used and maintained successfully on grades as high as 12%.

Advantages and Disadvantages.

Waterbound macadam does not require particularly rigid inspection during construction and can be built under almost any weather conditions except freezing. By its method of construction the voids between the large stone fragments are completely filled with solid material and there is no tendency to squeeze or creep as in some of the asphaltic macadams. If carefully built it maintains its longitudinal and transverse shape and is an easy riding road for both team and motor traffic.

Plain waterbound roads generally loosen up during the spring thaw and if subjected to much traffic at this time are liable to ravel. This trouble is not experienced with the bituminous macadams. Under heavy automobile traffic a plain waterbound macadam is not satisfactory as the machines remove the fine dust particles between the larger stones, leaving a rough surface which "kicks out" under team traffic. For this reason waterbound roads which are receiving much motor traffic are generally being treated with some kind of a dust layer or a bituminous protecting coat, that will better resist the wear of automobile travel.

Waterbound Roads Treated with Dust Layers or Protected by Flush Coats.

If waterbound macadam is kept moist by sprinkling with water, rapid disintegration under light machine traffic, traveling at medium speeds, is prevented. For light traffic, city or village streets, this is feasible, but the cost of sprinkling long stretches of country roads is prohibitive, and where the speed is high, as usually occurs on the main improved country roads, sprinkling alone will not satisfactorily protect a plain macadam.

The application of calcium chloride to a road surface keeps the dust down for a longer period than sprinkling with water, as this salt has the property of absorbing moisture from the atmosphere and condensing it on the road surface; on side roads two applications a season have kept the surface in good condition. The salt is applied with an ordinary agricultural drill, using about 1½ pounds per square yard for the first application and less for the succeeding applications. In Western New York the cost of the first application 12′ wide has been approximately $100 per mile. Complaints have been made that the application of too much calcium chloride has caused soreness to horses' feet, but using the quantities given above, no trouble has been experienced, to the writer's knowledge.[1]

The application of calcium chloride does not build up the road or form a wearing cushion that protects the stone; it merely prevents the fine surface dust from being blown away or removed by the machines.

[1] We are indebted to Mr. Frank Bristow, Superintendent of Repairs, New York State Department of Highways, for much of the data on Calcium Chlorine, Glutrin and Cold Oiling.

Glutrin.

Glutrin is a trade name for the liquid which is run out of sulphide tanks in the manufacture of pulp; it is distilled and the acids neutralized. It resembles molasses in color and consistency, is soluble in water, and is applied by sprinkling the surface of the road with one part glutrin dissolved in one or more parts of water, using from 0.3 to 0.5 gallons of the glutrin mixture per square yard treated. The road surface need not be swept if the dust is not more than $\frac{1}{4}''$ deep. It hardens the surface to a certain extent, and, apparently, prevents raveling if applied twice during a season on roads receiving a moderately heavy traffic. According to Hubbard an addition of 5% to 15% of semiasphaltic oil to the glutrin prolongs its efficiency, but such an addition tends to produce an oily mud in continued wet weather; glutrin alone does not produce this objectionable condition. Glutrin has been laid in New York State under an agreement with the Robeson Process Company of Ausable Forks, at a cost of \$0.04½ to \$0.06½ per square yard of surface actually treated.

Cold Oiling.

Macadam surfaces treated with light refined tar or asphaltic oil give a nearly ideal surface after the slippery, sticky condition has disappeared.

The road to be treated is swept clean of dust and the oil is applied by pressure sprinklers, using from 0.2 to 0.3 gallons per square yard. The surface may be dry or slightly moist when the oil is applied. It is then covered with a good quality of pea gravel, stone or slag screenings or a sharp, coarse sand. In Western New York the cost has ranged from \$0.02 to \$0.04 per square yard, including sweeping, materials (oil and cover) and the labor of placing.

To derive a season's benefit from the application of light oil or tar, the surface of the macadam must be thoroughly impregnated with the bitumen. Some of the lighter oils will evaporate. The cover will absorb some more. To get the greatest degree of saturation of road surface therefore, with a resultant freedom from dust and disintegration, the cover should be the smallest amount of stone that will smooth out or eradicate that "toothy" or "mosaic" effect of small shallow voids between the firmly locked top stone. (See page 100.)

On medium traffic roads, one application a season is sufficient and on light traffic roads one application will sometimes last for two seasons.

Hot Tar and and Asphaltic Residuum Flush Coats.

Bituminous flush coats are applied by sweeping the macadam carefully to remove all surface dirt as well as the stone or sand filler to a depth of about $\frac{1}{2}''$ below the top of the larger stone fragments. On this rough, clean, dry surface a heavy refined tar or a bituminous residuum of the binder grade is spread hot, using from 0.2 to 0.8 gallons per square yard. The binder is applied at temperatures ranging from 250° to 400° F., and is spread either by hand-sprinkling

pots or is sprayed on by specially devised pressure sprinklers. It is then covered with a layer of clean No. 2 stone ($\frac{3}{4}''$), or dustless screenings and thoroughly rolled. A well constructed surface of this kind resembles asphalt. It protects the macadam from raveling, is waterproof, forms a surface which takes the wear of the traffic from the large stone fragments, and gives a pleasing appearance. However, it cannot be laid in wet or cold weather; like asphalt, it is slippery and will not give satisfactory footing for horses on grades over 4%, and, unless laid evenly, will develop short, sharp waves or humps, which are very disagreeable for fast-moving automobile traffic. Some engineers advance the argument that by successive applications of such a flush coat a road can be maintained indefinitely without recaping, but as far as the writer has been able to observe, the roads become so humpy from continued treatment of this kind that recapping will be necessary to even up the surface on the score of comfort alone.

The use of a hot tar application on a concrete road will be discussed on Page 87. For use on an existing macadam road as repair, the authors believe that there is just one condition where a hot application should be specified; where an old road has begun to disintegrate unexpectedly, has passed the stage where cold oiling would rejuvenate it and funds are not available in the current year for resurfacing, then the hot oil or tar treatment may be used as a stop-gap to save it from complete disintegration for another year.

The cost of flush coats exclusive of covering ranges from \$0.12 to \$0.16 per gallon, or about \$0.09 per square yard. If applied to a macadam road during construction the cost of the plain macadam is increased approximately \$0.10 per square yard, making \$0.45 per square yard a fair comparative figure for flush coat and waterbound macadam construction.

The crown ordinarily used on flush coat roads is $\frac{1}{2}''$ to $1'$.

All bituminous binders have the following practical disadvantages whether applied as surface coats or as binders in bituminous macadams. The composition of residuum products is so complex and so easily varied that, to get uniform results, each shipment must be sampled and analyzed to insure certain required properties. In heating, care must be taken not to char the binder, as this destroys its life and effectiveness. They cannot be applied in wet or cold weather, which reduces the length of the construction season, and unless evenly spread a rough, humpy road results.

Bituminous Macadam.

Bituminous macadams are constructed in two ways, by the penetration method and by the mixing method.

Penetration Method.

Most of the bituminous roads in New York State have been built by this method.

The larger stone fragments, ranging in size from $1''$ to $2''$, to $1''$ to $2\frac{1}{2}''$, depending on the depth of the course, are spread and rolled;

a heavy grade of refined tar, residuum bituminous material, or fluxed natural asphalt, is then poured hot, either by hand or machines,[1] into the voids of the stone so that the stone fragments are covered with a thin coat of bituminous material; No. 2 stone, or dustless screenings are spread over the surface and broomed and rolled until the voids are filled; if a flush coat is to be used the excess filler is broomed off and the surface coat applied in the same manner as described for plain macadam. Where the flush coat is not applied, a wearing coat of clean screenings is spread over the surface.

The amount of bituminous material used as binder varies from 1.25 gallons to 1.75 gallons per square yard, depending on the depth of the course. The amount used for flush coats ranges from 0.2 to 0.5 gallon per square yard.

The cost of a one-coat 2″ bituminous top, using 1.25 gallons per square yard, will range from \$0.35 to \$0.45, and a 3″ one-coat top, using 1.75 gallons per square yard, from \$0.50 to \$0.60 a square yard. The flush coat using 0.4 gallon per square yard will add about \$0.06 to the above costs. For the purpose of comparison with madacam a fair set of prices is,

2″	Bituminous	top, one coat of bitumen ..	\$0.40	per	square	yard
2″	"	" flush coat............	\$0.45	"	"	"
3″	"	" one coat of bitumen .	\$0.55	"	"	"
3″	"	" flush coat............	\$0.60	"	"	"

Depth of Top Courses for Bituminous Macadams.

In 1910 New York State adopted a depth of 2″ using 1.25 gallons as binder and 0.5 gallon as flush coat per square yard.

In 1911 a 3″ depth was used with 1.25 gallons per square yard as binder and 0.4 gallon as flush coat.

In 1915 a 3″ depth was used with 1.75 gallons as binder and 0.5 gallon as flush coat.

A 2″ bituminous top will not fail by raveling, the defect mentioned for a 2″ waterbound macadam course, but it has certain constructional difficulties. To construct a 2″ course no stone should be over 2″ in its largest dimension. Because of the tendency to crack under concentrated wheel loads, none of the stone forming the main body of the course should be less than one inch in size. These limits of size are so narrow that difficulty has been experienced in procuring sufficient stone for top when crushing local material, and even when the stone is obtained from a commercial plant the same difficulty is often encountered. Also in spreading such a depth with stone ranging in size from 1″ to 2″, there will be places where the metaling is only one stone deep and the fragments do not fit as closely together nor have the same chance to interlock as in a deeper course. The spaces between these stones are filled with the No. 2 ($\frac{3}{4}$″) size, which

[1] The author has had better success with hand pouring for the first coat than with machine work. For thin flush coats, however, a pressure machine is absolutely necessary. If bitumen is poured by hand it must be poured across the road (never along the road) as this method of work largely eliminates humps formed by overlap. It is much easier to control the hand spread than the machine spread as to amounts and the stone spread is not disturbed or rutted up during the pouring.

wears more rapidly under traffic than the larger pieces and the road tends to become rougher than would occur if the $1\frac{1}{2}''$ stone fitted closer together. This last argument does not apply to flush coat roads.

The argument is often made that a $3''$ top will last one and one-half times as long as a $2''$ top because it has one and one-half times as much material, but the life of a top course rarely depends on its total thickness, as it will become so badly out of shape before the general elevation has worn down an inch that it will need recapping.

In attempting to meet these difficulties, $2\frac{1}{2}''$ and $3''$ courses have been built; as far as the author has been able to judge, the $2\frac{1}{2}''$ depth remedies the defects.

When pouring bitumen in the penetration method, a pocket of fine stone, dirt, etc., will sometimes hold the binder near the top in too great quantities; during hot weather the bitumen swells and, as the voids are full in these spots, it rises to the surface and forms a hump or wave. This trouble is not so frequent on either $2\frac{1}{2}''$ or $3''$ courses as on the $2''$ depth.

The writer's present opinion is that a $2\frac{1}{2}''$ depth, using about 1.4 gallons bitumen per square yard in one coat, will give satisfaction.

Crowns.

The crowns used on bituminous macadams range from $\frac{1}{4}''$ to $1'$ to $\frac{3}{4}''$ to $1'$; $\frac{1}{2}''$ to $1'$ is generally used and is apparently satisfactory.

Footing.

A single coat road affords good footing on any grade that will be adopted as suitable for heavy hauling; such a top course will not wash, which makes it easy to maintain on hills.

A flush coat, however, cannot be used to advantage on grades over 4%.

Advantages and Disadvantages.

Bituminous macadam without a flush coat provides good footing for horses; it will not ravel, is easy to repair for small depressions and ruts, is comparatively dustless and keeps its longitudinal and transverse shape well, making a comfortable riding road for fast travel. On the other hand, it will probably wear more rapidly than the flush coat construction as the traffic comes directly on the stone; it is subject to the practical disadvantages of construction of all roads where bituminous materials are used; it is not waterproof when first constructed; this last defect, however, is remedied by the traffic which grinds up the surface wearing coat and forces it into the voids. As a matter of fact, the combined action of traffic and weather puddles the road, and after about six weeks' use we can say that the road has a bituminous bond and a water-puddle finish.

Flush coat bituminous macadams are more dustless than the single coat, are more nearly waterproof when first built, look smoother at first, and will probably cost less to maintain. However, they do not

give as good a footing as the single coat and are liable to develop waves and humps disagreeable to fast traffic.

If a flush coat is used there seems to be no advantage in a bituminous binder, as the flush coat alone prevents raveling, and, if such is the case, the binder used throughout the depth of the course is a waste of money; a waterbound bituminous flush coat course might better be used. In choosing between a flush coat construction or a single coat bituminous madacam, the author believes that a single coat bituminous macadam is the better design; although it will probably cost more to maintain, the increased safety and comfort to the traveling public is worth the expenditure.

Mixing Method. — *Open Mix.* Type I.

The stone and bitumen are mixed hot in specially designed machine mixers. The mixture is then spread in the same way as sheet asphalt. A flush coat can be used if desired. The 1915 New York State specifications call for No. 2 stone ($\frac{5}{8}$ to $1\frac{1}{4}$)″ — when finished thickness is to be two inches or less and a mixture of No. 2 and No. 3 stone ($1\frac{1}{4}$ to $2\frac{1}{4}$)″; when finished top course is greater than 2″, the stone to be proportioned as directed by the Engineer. Approximately 18 gallons of bituminous material to each cubic yard of loose stone.

In this "open" mix, it is unavoidable that pockets of mixed top material will be placed which have a greater percentage of voids than the average. Whether or not a seal coat is used, these pockets will wear more rapidly than the surrounding pavement. In a similar manner, variations in the size of the stone will cause uneven wear. Both conditions tend to produce a humpy pavement after some use.

Mixing Method. — *"Tight Mix" or "Topeka."* Type II.

The stone, sand and bitumen are mixed hot in specially designed machine mixers. The mixture is then spread in the same way as sheet asphalt. The thickness varies according to the foundation. It is generally a consolidated depth of 2″ on a concrete foundation and $2\frac{1}{2}$″ on a firm macadam foundation. The various sizes of the mineral aggregate and the percentages of each are specified within certain limits varying slightly to meet gradations peculiar to the material available.

Because of the fine aggregate used in work of this type, there is not sufficient stability to withstand a mixed traffic and the surface ultimately forms in disagreeable waves.

Attempts have been made to prevent this waving by using a high penetration asphaltic cement which will permit the pavement to iron itself out. However, if a heavy slow-moving traffic be carried on this type of road, the surface will rut.

Apparently, the best results in mixed Bituminous Macadam have been secured when the coarse aggregate was used — stone between three-quarter inch and one and one-half inches in size, which were filled with a matrix of fine material of sand and bituminous material. Such pavements have sufficient "body" to materially decrease the "creeping" under use and take a more even wear than the open mixed type.

The prices for this type of top course run from

$$\frac{\text{Type I, } 61\tfrac{1}{2}¢}{\text{Type II, } 66¢} \text{ to } \frac{\$1.10\tfrac{1}{2}}{\$1.25} \text{ per sq. yd.}$$

Natural Rock Asphalts.

Sandstones and limestones containing a certain percentage of bitumen are known as rock asphalts. The most common source of supply for the Eastern States is Kentucky, and the product is known as "Kentucky Rock Asphalt." It is a sandstone containing about 7% to 10% of maltha. It is pulverized at the mine and is shipped and applied cold in the following manner: 2″ to 2½″ of stone, ranging in size from ¾″ to 1½″, are spread and rolled slightly. The rock asphalt is run through a shredding machine and spread over the stone, using approximately forty pounds per square yard. The whole mass is then thoroughly rolled, preferably with a six or eight ton tandem roller; forty pounds per square yard of pure rock asphalt is then spread as a wearing coat and well rolled; the rolling is continued intermittently for a number of days after the traffic is turned on the road. The cost of such a course has been about $0.70 per square yard in Western New York.

The crown ordinarily used is ½″ to 1′.

Advantages and Disadvantages.

The road is pleasing in appearance, is not as slippery as sheet asphalt, and will not ravel under motor traffic. However, it is hard to construct in cold weather, is not uniform, and will ravel in spots. It has defects in common with sheet asphalt of showing wear by developing short humps and hollows disagreeable to fast traffic. The steepest grade on which it can be used advantageously is about 5%, as it becomes slippery in cold weather, and in warm weather it sometimes softens enough to make hard pulling for heavy loads.

Amiesite.

Amiesite, a patented material made of crushed stone coated with asphaltic cement, has been used on many miles of road with good results. It is shipped cold in a friable and granulated state, spread on either macadam or concrete base and well rolled. Amiesite screenings are then spread and rolled, forming the surface. This construction costs about $1.00 per sq. yd., 3″ thick. It resembles asphalt in appearance and has the advantages and disadvantages of all roads of this class. It is particularly adapted for small jobs where it would not pay to set up an asphalt plant or where suitable asphalt materials are not locally available.

For further information see chapter on Cost Data and Specifications.

Other Surfaces of a Bituminous Nature.

There are any number of patented pavements that can be classed under this head to which we cannot give space.

Sheet Asphalt and Warren Brothers' Bitulithic are used in unusual cases, but constitute such a small percentage of the mileage that for information concerning them we refer the readers to books by Richardson, Hubbard, Tillotson, etc. We includes some notes on inspection of construction, page 351.

Brick Pavements.

The ordinary brick pavement construction is probably familiar to most readers. On a concrete foundation 5″ to 7″ in thickness a sand cushion varying in depth from 1″ to 2″ is spread and the paving brick are laid on this sand bed so as to break joints; the brick are well rolled and the joints are filled with sand, cement grout or paving pitch. Longitudinal expansion joints of bituminous material are provided next to the curbs or edgings; transverse expansion joints, space 30′ to 50′ apart, are used by some designers. The latest practice tends to make the sand cushion as thin as possible, acting merely as an evener of the concrete surface. It is also rare to find any material but cement grout used for filler. The use for traverse

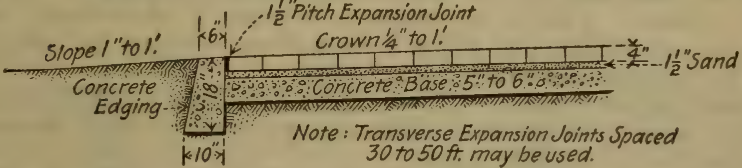


FIG. 26. — Brick Pavement, Flush Edging

expansion joints is also being relegated to the back ground. Premolded alsphaltic strips are designed for longitudinal expansion joints in most recent practice. In the last few years the former theory that the 1½″ sand cushion prevented crushing of the brick and gave the amount of resiliency necessary to a pavement of this type has been disputed, and apparently successfully so, by the increased use of a cement sand bed. Upon the prepared foundation a bed of cement and sand consisting of one part cement to four parts of approved sand is spread not more than 1″ in depth. The sand and cement are thoroughly mixed dry until a uniform color is obtained, struck off with a template and rolled with a hand roller weighing about 300 lbs. After the brick are laid thereon and before grouting, the rolled bricks are thoroughly wet by sprinkling. It is important that the bricks be well wet so as to set up the cement sand bed. It is probably true that the use of a mortar cushion reduces the tendency of the brick to loosen near cracks.

In 1915 several experimental brick pavements were constructed where the mortar cushion and brick were laid upon concrete which was still plastic. Concrete foundation was shaped by template and the brick laid, inspected and rolled with a hand roller before the cement had taken its initial set. This is immediately followed by grouting. It is too early to say whether or not this so-called "mono-

lithic" construction will be successful. The expense and difficulty of manipulation are increased and it is doubtful if any material advantages are attained.

Brick Pavement construction is essentially rigid, intended to withstand heavy traffic. The cost, including foundation and surfacing, ranges from about $1.60 to $3.00 per square yard, the average price in Western New York being about $2.00.

Brick pavements on heavy traffic roads have been extensively used in Ohio and New York. Macadam foundations for brick surfacing have not proved satisfactory in the Northern States, as the surface is too rigid and cracks under the heaving action of the frost. Even on a concrete foundation longitudinal cracks often develop from this same action. It is more difficult to prevent this on country roads than in cities where the sewers keep the earth sub-grade comparatively dry, and the necessity for a center drain under the concrete base is being recognized by many designers. Some engineers believe that the 1 to 1 cement grout in general use is too strong, and that if a weaker grout or a sand filler were adopted in its place the heaving frost action would merely separate the bricks slightly instead of breaking them and that as the road settled they would fall back into close contact. This is an attempt to make a theoretically rigid construction flexible and seems to be striving to adapt the construction to conditions for which it is not fitted.

Longitudinal Cracks. — These cracks have been carefully studied, as they seem to be the most discouraging feature of brick pavement construction on country roads.

Mr. Wm. C. Perkins, Chief Engineer of the Dunn Wire Cut Lug Brick Co. states from a careful examination of a large mileage of brick roads built under his supervision, that longitudinal cracks have always occurred within 2′ or 3′ of the center of the road; that the cracks extend down through the concrete base and that less difficulty is experienced in preventing them as the crown of the pavement is reduced. From these observations he has been led to experiment with a concrete base having a perfectly flat bottom, as shown in figure 26A, crowning the road by making the concrete thicker in the middle than on the edges. The claim is made that this style of construction is helping to prevent such cracks.

Transverse Expansion Joints. — The use of transverse expansion joints has not been successful locally. Difficulty has been experienced with the brick loosening at these joints, and whenever a temperature heave has occurred it has appeared at the joint. Their use has been abandoned for rural roads in Western New York.

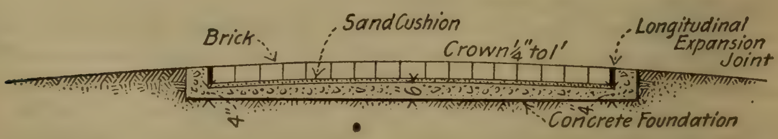


FIG. 26 A

The crowns in use on brick pavements range from $\frac{1}{4}''$ to $1'$, to $\frac{3}{8}''$ to $1'$. For the methods of figuring ordinates for parabolic crowns see page 262.

Brick pavement does not give a good foothold for horses on grades above 5% unless some special form of brick is used. For steep grades, on heavy traffic roads, it is better practice to use some form of stone block.

Stone block pavement, including concrete foundation, costs from $2.70 to $3.30 per sq. yd. It is suitable for the steepest grades that are constructed.

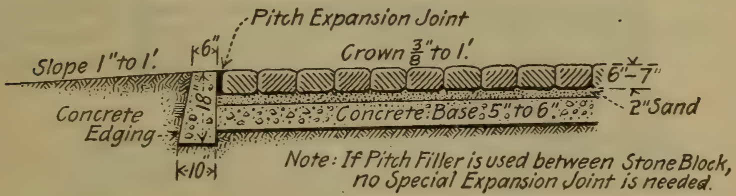


FIG. 27. — Stone Block Pavement, Flush Edging

Where stone blocks are used on hills it is better practice to use second quality blocks; these blocks are identical with the first quality blocks as to material but are not dressed as carefully and cost about fifty cents per square yard less; their rougher surfaces and wider joints afford better footing. For the difference in size and joints see specifications, Medina Block, page 396.

The first cost of brick pavement for country roads restricts its use to roads where it can be conclusively proved that macadam will not be suitable.

Asphalt Block

The asphalt block pavement laid in New York State has been very satisfactory. The proportion of ingredients is about 70% crushed rock, usually trap, which has passed a $\frac{1}{4}''$ ring, about 20% limestone dust to act as filler and approximately 10% of asphaltic cement, molded under a pressure of 2 tons per sq. inch of block having a 2″ depth. This produces a dense asphalt much superior to the ordinary sheet.

The asphalt used is Trinidad. This is refined and fluxed so that the resulting A. C. may be varied as to adhesiveness, penetration, etc. to meet varying conditions peculiar to different localities.

The penetration is made high enough to give a certain amount of pliancy to the block, to avoid crumbling at the edges and to make the joints self-healing.

The use of blocks containing steel anchors, laid across the road, approximately fifteen feet apart, has eliminated any movement of the block under traffic. These blocks are placed at more frequent intervals on curves. Block pavements have been laid using a longi-

tudinal row of these anchor blocks in place of edging. The results appear satisfactory.

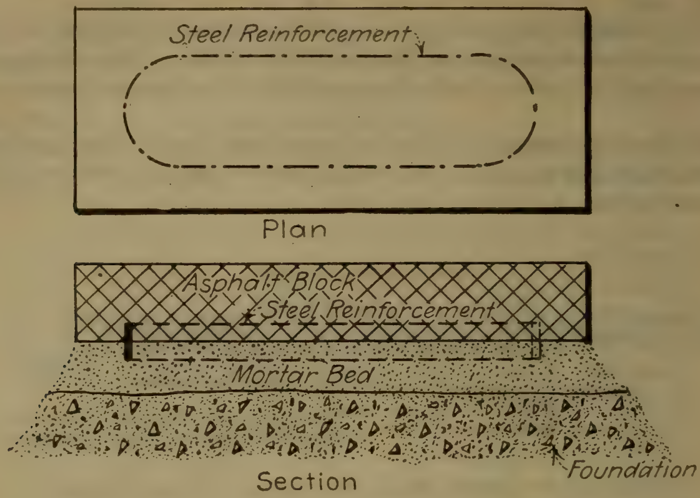


Fig. 27 A

After the base is prepared a mixture of 1 to 4 Portland cement mortar is spread $\frac{1}{2}$ inch thick. This mortar bed is carefully screeded and the block laid thereon, joints being broken at least 4 inches.

Asphalt Block Data

Highway No.	County	Mileage	Bottom Per sq. yd.	Top Per sq. yd.	Per Mile 16′—26′
5357	Westchester	0.95	$0.61	$1.49	$26,593
5375	"	1.34	Old Mac	1.69	18,114
5388	Rockland	2.16	" "	1.70	[1] 27,025
			0.59	1.70	[1] 32,525
1153	Niagara	0.97	0.60	1.37	[1] 31,800
5482	Westchester	1.16	0.66	1.50	29,270
1167	"	1.28	0.61	1.38	24,245
1053	"	1.45	Old Mac	1.60	21,205
5528	Warren	0.61	0.59	1.60	35,990
5356	Westchester	0.53	Old Mac	1.63	[1] 26,960
5361	"	0.68	0.61	1.44	[1] 23,512
5362	"	0.25	0.67	1.37	25,569
5364–A	"	0.31	0.47	1.47	23,166
5373	"	2.85	0.58	1.52	———
			Av. 0.599	Av. 1.533	

[1] Costs from preliminary estimate.
All costs not marked with star from bid prices.

An interesting comparison with brick occurs in the "pinning in" at curbs. Instead of bats being broken by hand, a large mechanical shear is used. Each fractional block is measured and cut to fit exactly.

After being laid, the pavement is given a light coat of sharp sand which is broomed into the joints. Traffic is permitted in four or five days.

Advantages. — The pavement shows a smooth, uniform surface, dustless and practically noiseless. Its life has yet to be determined. Pavements that have been down ten or fifteen years are still in good shape. Within a reasonable freight radius from the point of manufacture, it can be laid for approximately the cost of brick.

Disadvantages. — A mist or light rain makes the pavement very slippery. It should not be used on grades over 4%.

CONCRETE PAVEMENTS

Introductory

Inasmuch as there is some difference of opinion as to the value of this type each author has written his interpretation of the available facts.

Concrete Pavements

By W. G. Harger

Many miles of these roads have been constructed in the last few years.

The construction has varied from poor 1 to 6 pit run gravel concrete to first-class $1:1\frac{1}{2}:3$ stone concrete 6″ to 9″ thick.

There is enough data to conclude that cheap concrete is a failure. An effort was made to protect the surface of such a mix with a thin bituminous surface coat of asphaltic oils or tars. These coats have not been successful as they peel off and produce an unsightly, rough riding and a high maintenance cost road.

The type of concrete road now being built and which has many enthusiastic supporters is a first-class $1:1\frac{1}{2}:3$ stone or screened gravel concrete which takes the traffic directly on its surface. The concrete is carefully manipulated (see specifications, page 443). The ordinary section used is shown in figure 27B. Expansion joints of creosoted wood or patented steel plates with tarred paper filler are provided at intervals of approximately 30 ft.* The cost of this pavement has been from $1.10 to $1.50 per sq. yd. They have the advantages and disadvantages of all rigid types of construction. They should not be used on grades over 5%.

Pavements of this class have been built on roads having light, medium and heavy traffic and are advocated by Cement Manufacturers as an economical road under all classes of traffic. The author

* The author personally believes that better results will be obtained by eliminating these joints altogether. The artificial joints are sources of weakness in that they tend to localize the wear. Apparently less wear occurs at a natural crack and it is certain that a smoother riding road is obtained.

believes that while this type has its place that a great mileage is being constructed which from an engineering viewpoint is not justified. The roads have not been down long enough to obtain reliable data as to their length of life before resurfacing. Considering in a general way, however, what we know of the material and the action of the weather and traffic on rigid types of pavement, an allowance of 10 to 15 years would appear liberal. When they arrive at the point when they need resurfacing a large expense is involved. It has been demonstrated that cheap thin bituminous coats have not been successful; it is not possible to successfully resurface with a thin layer of concrete which means that probably Asphaltic Concrete, Asphalt Block, Brick or some other form of block or cube pavement will be used at a cost of from $9,000 to $16,000 per mile. The fact that resurfacing when it occurs requires such a large expenditure eliminates this type from use on any but the more important roads which constitute a small percentage of the mileage of any large system.

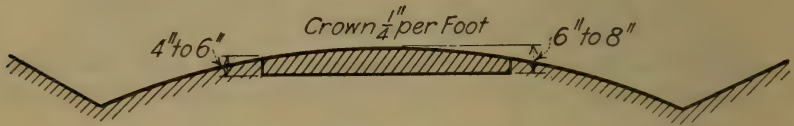


FIG. 27B

With the data at hand the indications are that this type is a good design for the heavier Class II traffic roads where it is desirable to keep the first cost as low as possible and where it is expected that the necessary money will be available in later years for an expensive resurfacing.

The fact that the first cost is moderate and the maintenance is low for a number of years blinds a great many highway officials to the final cost of upkeep, or if they are not blind many of them figure that the roads will outlast their tenure of office and what do they care about their successors.

Concrete Bituminous Roads

By E. A. Bonney

Some four or five years ago, a tremendous wave of publicity swept concrete roads into the limelight. The construction at that time consisted of a second-class concrete base with a skin coat from $\frac{1}{4}''$ to $\frac{3}{4}''$ in depth, composed of screenings, mixed with hot oil or tar, and sometimes a combination of the two. The base was laid without joints and gravel or any kind of stone was used for aggregate.

Under this type at least a dozen patented pavements were developed practically none of which have to any degree borne out the extravagant claims made at that time.

The bituminous skin coat has not been satisfactory. It is subject to all the disadvantages of other bituminous macadams and with few exceptions has not adhered to the concrete for any length of time.

There is a road known as the Bedford-Goldens Bridge State Highway in Westchester County, on which 2.67 miles of concrete base had been laid when the original contract was canceled. The unfinished portion was covered with an experimental skin-coat treatment which today is as sound and intact as when laid. Work was finished in the early summer of 1915. The road was subjected to the enormous automobile traffic peculiar to Westchester County all season. A brief description follows:

The concrete was cleaned, all dust, dirt or caked material removed. It was then coated with a cold application of low carbon tar, very light grade, almost a creosote. This was spread about $\frac{1}{10}$ gallon per sq. yd. and allowed to dry for two hours. About $\frac{1}{3}$ of a gallon per sq. yd. of Bit. Mat. "T" low carbon binder was then applied hot and covered with approximately 37 lbs. of No. 2 stone per sq. yd. A second coat of $\frac{1}{3}$ gallon per sq. yd. was then applied and covered with about 32 lbs. per sq. yd. of No. 1 stone.

This treatment so far looks extremely well and has not broken away from the concrete. It is still too early to classify as a success.

The cost of the top course only was $17\frac{1}{2}$¢ per sq. yd.

Base cost 68¢ making total of 85¢.

Concrete Pavements

By E. A. Bonney

1–$1\frac{1}{2}$–3 Mix

Concrete pavements are showing as each season passes by, that they are worthy of much more consideration than has been given them up to the present time. For roads subjected to heavily loaded and slow moving vehicular traffic or for roads so located or so traveled that any type of macadam road would be subjected to costly maintenance, the concrete pavement has come to stay. The wear seems to be inappreciable and because of the flat crown, traffic is spread over the entire width of metal.

Great care must be exercised in the selection of aggregates. Many sands that are considered good enough for ordinary concrete work will not give satisfactory results in concrete pavement. Stone or gravel should be limited to those showing a high coefficient of wear.

Considerable attention should be paid to the percentage of voids in the sand and stone. Experiments should be made to determine approximately the mixture giving the lowest percentage of voids. The authors do not believe in the blind adoption of a specified mix. It is often essential that the mix be varied to correspond to the gradation of available sand and voids in coarse aggregate.

Several containers of uniform volume and a pair of scales are all the apparatus necessary to show whether or not the specified mix is the best mixture for the aggregates available.

The approximate percentage of voids may be found by water. By making up several concrete cubes or cylinders of the same volume, beginning with the specified mix and varying the others as

indicated by the percentage of voids, the heaviest product will indicate the proper mixture.

Any data given herewith is based upon a one-course road. The authors are not personally familiar with two-course roads.

Bulletin No. 249 of the Office of Public Roads, U. S. Department of Agriculture, cites the advantages and disadvantages of concrete highways as follows:

"Advantages:

1. As far as can be judged, they are durable under ordinary suburban and rural traffic conditions. While it is true that there are no very old concrete pavements in existence, the present condition of many of those which have undergone several years' service would seem to warrant the above statement.

2. They present a smooth, even surface, which offers very little resistance to traffic. In the past the surface of concrete pavements have sometimes been roughened in order to insure a good foothold for horses. This practice has now been abandoned, except on very steep grades, because it tends greatly to accelerate deterioration of the pavement, and because the smooth surface has been found to afford a fairly satisfactory foothold under all ordinary conditions.

3. They produce practically no dust and may be easily cleaned.

4. They can be maintained at comparatively small cost until renewals become necessary.

5. They may be made to serve as an excellent base for some other type of surface when resurfacing becomes desirable.

6. They present a pleasing appearance."

"Disadvantages:

1. They are somewhat noisy under horse traffic.

2. There is no method of constructing necessary joints in the pavements which will entirely prevent excessive wear in their vicinity. Furthermore, joints do not altogether eliminate cracking and wherever a crack develops it must be given frequent attention in order to prevent rapid deterioration of the pavement.

3. They cannot be readily and effectively repaired as many other types of pavements."

This summation of concrete roads in general seems eminently fair. We believe, however, that to the disadvantages should be added the inevitable rut which appears between the edge of the concrete and the earth shoulder. These ruts are dangerous to fast-moving traffic and require constant maintenance for their elimination unless the shoulders are armored with crushed stone or gravel for two feet or more from the concrete.

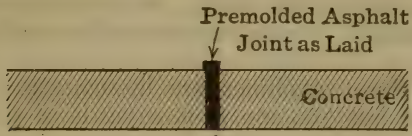
The questions of reinforcement and joints are still the subjects of much discussion among engineers.

The item of reinforcement largely increases the cost of the roads and it is yet too early to say that the added expense is justified.

The joint problem affords an unlimited field for a variance of opinions. Few engineers are satisfied with any of the existing armored joints, patented or otherwise.

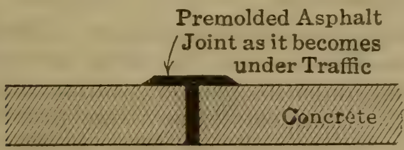
The author believes that experience to date has divided the problem of joints into two fields: i. e. on roads under continued maintenance a bituminous joint will prove satisfactory and is renewable at small cost; on roads which receive spasmodic maintenance or none at all, some sort of steel joint should be used.

On New York State work where maintenance is continuous the most satisfactory joint to date is of premolded asphalt, which is so placed that it projects from $\frac{3}{8}''$ to $\frac{1}{2}''$ above the surface of the concrete; thus



A

A combination of hot weather and traffic spreads the asphalt out in this manner, leaving a bituminous mat over the joint.



B

For concrete roads not under maintenance, the better joints are being made of soft steel tempered to the same relative hardness as the concrete. A hard steel joint simply transfers the point of wear from the joint-edge proper to the concrete back of the joint.

The proper length of concrete slabs between joints is another subject of speculation. Many roads are now being built with varying distances between joints in an endeavor to determine how few can be used with success.

The average cost of this type in New York State for 6″ depth of pavement is $1.121 per square yard of pavement only. Total average cost for mile of completed highway, including excavation, drainage structures and pavement, is $15,320.

Small Stone Block Surfacing.

In Germany, Hungary, Austria, and England a surfacing made of granite blocks, ranging in size from $2\frac{1}{2}''$ to 4″, has been used successfully. This pavement is known as Kleinpflaster in Germany, and as "Durax" armoring in England. The stone cubes must be cut with considerable accuracy in order to give a smooth and durable surface.

The blocks are laid on a thin sand cushion of about $\frac{3}{8}''$ depth, on either a macadam or concrete foundation; they are thoroughly

rammed to give a firm bearing and the joints filled either with clean sand flushed in, or a bituminous filler. The joints do not exceed $\frac{1}{4}''$ in width. The courses of cubes are laid either diagonally to the direction of the traffic or in concentric rings.

Where the stone is broken by hand the cost is high and it would be impossible to consider its use for rural roads in this country. A machine[1] has, however, been developed in Europe for breaking these cubes which is claimed to produce a satisfactory product at a reasonable rate. It is a belt-driven friction drop-hammer having a stone chisel mounted on the anvil; the hammer head is shaped like a stone-cutter's sledge. The power needed for each machine is about $1\frac{1}{2}$ H. P.

About 400 of these machines are in operation, and a plant in Sweden is turning out 700,000 square yards of pavement per year with 62 machines.

Provided the pavement can be laid for $1.00 to $1.25 per square yard, it seems a type that must be seriously considered. A price as low as this, however, would necessitate the use of convict labor in the manufacture of the cubes.

McClintock Cube Pavements. BY W.G. HARGER

This is a patented pavement devised by J. Y. McClintock, County Engineer of Monroe County, N. Y. It is very similar to "Kleinpflaster" except that under his patent artificial cubes as well as stone cubes are proposed. It appears to be a very promising type.

The construction is essentially as shown in figure 28 and consists of a top course of $2\frac{1}{4}''$ cubes placed on a thin sand cushion supported by either a macadam or concrete base. The cubes have been made of concrete, vitrified paving brick material and stone as in Continental practice.

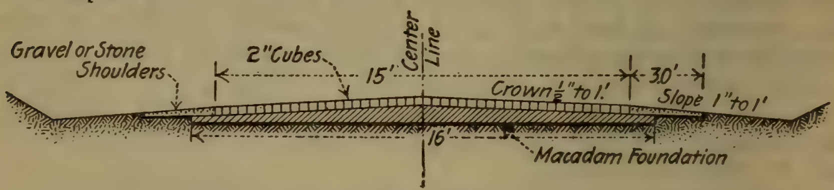


FIG. 28

They are loaded, hauled and dumped like broken stone; laid in close contact by means of a pallet and rake 128 at a time on a sand cushion $\frac{1}{4}$ to $\frac{1}{2}''$ thick, no care being taken to break joints. They are then rolled to bring to an even and firm bearing; the joints are filled with a sandy loam and the surface treated with a light coat of light road oil or cold tar if the foundation is macadam. The joints are grouted if the foundation is concrete. Temporary shoulders of $2''$ plank are put down during the laying of the cubes after which they are removed and replaced with broken stone or gravel as shown in figure 28.

[1] A detailed description of this machine is given in Engineering News, March 27, 1912.

The experience of the past six years has shown that this form of construction using a sand-tarred joint is flexible under frost action which makes it suitable as a surfacing on a macadam base. It keeps its shape under traffic and shows no tendency to ravel or break down at the edges and can be successfully held with a macadam or gravel shoulder without the formation of a rut along the edge which is a difficulty always encountered where a rigid edging is designed. It gives a satisfactory surface in both wet and dry weather and can be laid late in the season. The cubes require comparatively little inspection and can be successfully used as a patch in maintenance with simple manipulation. They reduce the tonnage and freight cost where imported materials are required. Concrete cubes have not served satisfactorily, failing in spots, but this is to be expected as it is not a reliable material for a road surfacing of this nature (that is for such small units). Vitrified shale cubes with wide sand joints laid on a macadam base have shown ability to stand medium traffic. Vitrified shale cubes with close tarred joints laid on a thick macadam base serve very satisfactorily under moderately heavy traffic, and the indications are that these cubes laid on a concrete foundation and grouted will meet all but the heaviest traffic satisfactorily.

Consider briefly the present tendencies in highway construction. There are two distinct types; the flexible form represented by the macadams and the rigids types, such as brick, asphalt, stone block, etc. having concrete foundations. Each has a distinct field and their relative economy depends largely on the traffic.

It is sufficient for this discussion to note that macadams are suitable for light and medium traffic (Classes II and III); that they are able to withstand climatic changes better than the rigid pavements and that with a moderate yearly expenditure they can be kept in good condition when used under the volume of traffic stipulated.

They fail either under high velocity traffic or heavy hauling; the first being a surface failure and the second a foundation failure for most of the roads in this locality but a surface failure for some which have a thick well-consolidated base. That is, if some better flexible surface can be used on a first-class macadam foundation, this type of road will be able to handle a heavier volume of traffic than at present with a moderate maintenance charge. The indications are that the Brick cubes with sand-oiled joints will serve this purpose.

The rigid roads develop defects due to temperature changes; frost heave and the settlement of fills. Subsequent movement is localized along these lines and eventually expensive repair and reconstruction is necessary. Under heavy traffic, however, the cost is less than for the macadam type and the inconvenience of continual repairs is avoided.

The first cost of Brick and Asphalt block which are generally considered the best of the rigid types is so high that designers often hesitate to use them where they are actually needed. If it were possible to reduce the cost and yet obtain practically the same class of improvement a larger mileage could be used to advantage.

The indications are that the Brick cubes on a concrete foundation will serve this purpose at a cost of about $0.40 per sq. yd. less than the present paving brick.

Highway designers do not hesitate to use madacam for the light traffic roads or expensive rigid constructions for the extremely heavy traffic; the great mileage that lies on the verge of either form of construction offers the real difficulty. It is for this class of road that the cubes are particularly adapted by reducing the cost of brick and increasing the efficiency of macadam. This applies also to the resurfacing of concrete and macadam roads.

The author believes that provided this type fulfills its present indications that it will meet a recognized need in highway construction and for this reason has given more space than perhaps is justified to a method which has not been tested out by a large mileage of construction.

A reasonable cost of the brick 2″ cube surfacing is approximately $0.95 per sq. yd. in Western New York. This form of road material is adaptable to manufacture by convict labor.

Rocmac.

Rocmac is another patented pavement which deserves mention, as the roads which the author has seen built by this method compare favorably with other types of construction. The claim is made that, under favorable conditions, it will cost only fifteen cents per square yard more than plain macadam. The only available example of cost details given below is hardly a fair sample of what can be done.

We quote an extract from the 1910 report of the New York State Highway Commission: "Experimental pavement according to the Rocmac System as laid over the westerly portion of Buffalo Road, Section No. 2, County Highway No. 83, located in the Town of Gates, County of Monroe, New York.

"The Rocmac system differs from ordinary macadam construction in that the aggregate of crushed stone is cemented together by a matrix composed of limestone dust (as rich as possible in carbonate of lime) mixed with a solution of silicate of soda and sugar, the silicate of soda combining with the carbonate of lime, an unstable compound, forming silicate of lime, which is a very stable compound.

"The materials used in this experiment were Leroy limestone flour for the matrix, being the entire crusher product which would pass a screen of $\frac{1}{4}$-inch mesh, and Akron limestone No. 3 size with some No. 4 size mixed for the aggregate. The No. 3 size being retained on a screen of $1\frac{1}{4}$-inch mesh and passing a screen of 2-inch mesh, the No. 4 size being retained on a screen of 2-inch mesh and passing a screen of $3\frac{1}{2}$-inch mesh.

"The delivery point for material shipped by rail being Coldwater Station, a dead haul of one mile to the beginning of the work.

"The supervision given this work consisted of occasional inspections by the division superintendent of repairs and the inspector in charge of this section, neither of whom could devote much time to this particular work without interfering with other duties. Had the work been constantly directed by a competent foreman more progress

would have been made and the cost probably would have been decreased.

"The method pursued during the laying of this surface was to scarify by hand the original foundation course, removing all loose material by brooming, upon this prepared foundation to spread the matrix composed of limestone dust and solution, to an average depth of about two inches, upon this spread the crushed limestone aggregate to such a depth as would give finished rolled thickness averaging about $3\frac{3}{4}$ inches when properly crowned, then rolling same until thoroughly consolidated and continuing rolling and sprinkling with water by hand until the matrix which flushed to the surface in the form of grout has nearly disappeared, when the pavement is covered with a light coat of screenings and considered complete.

"The total length of this resurfacing extending from Station 237 to Station 275+ 76 is 3,876 lineal feet, aggregating an area of 6,890 square yards surface upon which was used 1,094 tons of No. 3 and No. 4 crushed limestone, 520 tons of limestone flour and 4,050 gallons of silicate of soda solution.

"Deducting from total expenditure materials not used and expense of labor trimming shoulders and ditching would leave total cost of this resurfacing including all material and labor necessary to form pavement complete in place $6,400.82 or $0.9288 per square yard. This expense is itemized as follows:

Item	Total	Per Sq. Yd.
Cost of Stone f.o.b. cars delivery point.	$2,026.59	$0.2941
Cost of Rocmac solution	617.28	0.0896
Cost of teams hauling stone, solution, water and coal	1,408.79	0.2044
Freight and duty on solution	408.61	0.0593
Roller and coal	547.28	0.0794
Labor	1,341.64	0.1947
Tools, tank, blacksmith, oil and wood	50.63	0.0074
Total	$6,400.82	$0.9288

"The average price paid per ton for all stone f.o.b. cars at delivery point is $\$1.25\frac{1}{2}$; price paid per hour for labor $0.22; for teams $\$0.56\frac{1}{4}$ per hour; roller rent $10 per day.

"During the progress of this resurfacing traffic was not interfered with at all, all traffic being permitted to go over the work in whatever stage of progress. This is an advantage worthy of consideration.

"The finished surface after five months' traffic has the appearance of a well-constructed macadam road, being hard, smooth, well bound, and clean, no discoloration being apparent except immediately after a rain, when it shows light brown in spots, due to the solution, which being soluble in water comes to the surface.

"No ravel developed during continued dry weather when freshly laid and under traffic; road is relatively dustless; this, however, depends upon the percentage of silica in the stone used. The theory being that whenever the pavement becomes wet the solution is brought to the surface, resulting in absorbing and hardening down any fine material which had been produced by the abrasion of tires.

"It can be laid in all excepting freezing weather, and while smooth yet it is sufficiently rough to afford good footing for horses and rubber tires. There is nothing entering into the construction to soften under high temperature and nothing to form mud in wet weather. It is claimed to be self-healing, due to continual chemical reactions taking place whenever the road becomes wet."

CONCLUSION

In this chapter the authors have attempted to show the approximate costs of the different styles of construction in general use or such experimental tops which they have seen that promise well. The costs given can be considered as relative only, to be used in a comparison of the various constructions and are based on roads in Western New York.

In selecting the kind of pavement for various traffic requirements, good present practice calls for Brick, Asphalt Block or Asphaltic Concrete for Class I traffic at a cost for a 16′ road ranging from $20,000 to $28,000 per mile.

For Class II, Bituminous Macadam, First-Class Concrete, Waterbound Macadam with Bituminous flush coats, Amiesite, and in the near future probably small blocks or stone cubes at a cost for a 16′ road ranging from $11,000 to $18,000.

For Class III, Waterbound Macadam treated with Calcium Chloride or light road oil or tar at a cost for 12′ to 16′ road of from $8,000 to $11,000.

For Class IV, Bituminous Macadam, Concrete, Waterbound Macadam with Bituminous flush coats, Amiesite, Asphalt, etc. at a cost of $12,000 to $20,000 per mile.

The type selections as given are based on satisfactory performance under traffic and moderate maintenance cost.

MAINTENANCE

In the development of any system of highways the methods and cost of maintenance become increasingly important. The rapid growth of motor traffic in the last few years has changed both methods and cost, making it necessary to give new figures which are reliable for present traffic conditions. We have therefore confined ourselves in the discussion to recent costs with which we are familiar in order that in stating general conclusions proper allowance is made for unusual conditions not shown in the reports of various State Highway Departments.

The discussion will be based on the general maintenance costs and methods employed on 5600 miles of New York State Highways

of all types for the year 1915 and detail costs on 600 miles of roads in Western New York for a term of years.

We are indebted to Mr. Frank Bristow for the following discussion of general maintenance methods and summarized costs. It should be borne in mind that the discussion and costs apply to territory subjected to severe winters.

Maintenance of Improved Highways

By Frank W. Bristow,

N. Y. S. Dept. of Highways, Division of Maintenance

Maintenance comprises keeping the paved roadway surface in as nearly perfect condition as possible, keeping the earth shoulders smooth and safe for traffic; the drainage system free from obstructions; all structures in good repair; removing obstacles to vision as brush or overhanging branches; and cutting tall weeds and grass.

If the work of maintaining improved roadways is consistently performed through successive years it is certain that the efficient life of such roads will be lengthened. Maintenance should commence when construction leaves off, because in order to effectively and economically maintain improved roads it is necessary that the roadway be in a good state of repair at the time the maintenance work begins, and should the pavement be so worn as to be structurally weak it is not economy to postpone resurfacing.

Maintenance work, including surface treatment with bituminous material and cover, should be distinguished from extensive repairs involving resurfacing or reconstruction.

Maintenance of Macadam Roads

It is especially desirable that all surface treatments be completed as early in the season as possible; say by mid-summer to permit traffic to enjoy the greatest benefit from such treatment, the season of heaviest motor traffic being from the middle of July to the middle of September. So far as practicable the correction of surface defects such as ruts and depressions should precede the surface treatments.

While the elimination of dust on macadam roads is desirable as adding to the comfort of the traveling public, it is necessary from the maintenance point of view, inasmuch as dust means deterioration of the road which if permitted to continue results in a raveled condition and the macadam will disintegrate. Surface treatment with oil or tar also tends to seal or waterproof the pavement. Horse-drawn steel-tired traffic tends to destroy an oiled surface mat, while rubber-tired motor traffic is beneficial.

It is good practice not to oil macadam roads upon which horse-drawn traffic greatly predominates, or new waterbound macadam which has not been under traffic at least two months, or extremely shady roads.

The usual foundation defects which develop in gravel and macadam surfaces are ruts, due to a soft condition in the earth sub-grade, depressions due to settlement of fills which commonly develop at locations where new culverts were constructed and frost boils.

Shallow ruts and surface depressions are corrected by being filled in with crushed stone of as large size as the depth of depressions will permit, the same being well tamped into place, and more lasting results are obtained if a proper grade of bituminous material is used to firmly bind the new stone; light asphaltic oils and tars have been used for this purpose with unsatisfactory results, in that patches made by this method do not endure, the experience being that the material forming the patch is pushed ahead by traffic leaving the original depression exaggerated by the bunch of new patching material at the end. Heavier binder grade material has been used; a patch by this method is durable but does not wear away as rapidly as the adjacent surface resulting in a high spot in time. To date our experience is that an asphaltic emulsion for cold patching is most satisfactory, being nearly fool proof and requiring no equipment but a broom and shovel. This material is not recommended for use with stone of greater size than will pass a one and a quarter inch ring. In using this material the depression to be repaired should be swept clean, so as to be free from mud or loose material, and tamped full of a mixture of the emulsion and broken stone. Such a patch will require an hour or two to set. The proportions of the mixture required are, where the stone used are uniform in size about three-quarters of a gallon per cubic foot of stone, where the stone are graded about a gallon per cubic foot. This mixture may be made in moderate quantities as stock for use as required. Ruts in gravel surfaces may be eliminated by the use of a hone early in the season. Deep ruts indicate necessity of either subdrainage or reinforcement of the foundation; an inspection should determine which is the proper remedy. On side hill roads frequently a deep drain in the upper side ditch to intercept the ground water will be effective; where reinforcement is decided as necessary, usually sub-base construction about eight feet in width will be sufficient. Field stone, quarry spalls, broken stone, slag or gravel are proper materials for such reinforcement.

Frost Boils so called are caused by wet spots in the earth foundation freezing and heaving, later when the frost leaves and the foundation soil is soft the thin macadam crust tends to break through under loaded wheels. These spots which usually occur where the road construction is in a cut, should be excavated, and drained if practicable; any wet clayey soil or silt removed and replaced by gravelly material, field stone, quarry spalls or other good material, the macadam is then replaced.

Ravel is the term applied to describe the condition where the fragments of broken stone become loosened from the body of the road, due to the binding agent failing to perform its function. Bare toothy or a pitted condition of surface are the varying degrees of a slightly rough surface due to the interstices between the fragments of stone not being filled flush with the binding material or when the wearing surface has innumerable extremely slight depressions. Dust, which is self-explanatory.

The remedy for raveled, pitted or dusty condition is a surface treatment of bituminous material and cover.

These treatments are generally made using a grade of asphaltic residuum oil or a refined tar product which can be applied cold, or which requires very little heating, and better and more uniform results are obtained where a pressure distributor is used. If a pressure machine is used not less than twenty pounds should be required.

Asphaltic base oils, or tar products having a bituminous content of from 40 to 60 per cent may be applied by gravity sprinkler, but 60 to 75 per cent asphaltic oils or tars containing 60 to 70 per cent of pitch are preferably applied by pressure. Uniformity in application is important.

As to the relative merits of asphaltic Residuum oils, cut back asphalts, high carbon, or low carbon tars there is a diversity of opinion. Relative cost and durability will naturally be the considerations controlling the selection. The material which is the cheaper at one delivery point may not be at some other. As to durability it is doubtful if there is any advantage as between the asphalt and tar-products. When applied, the tar material appears to take a set faster than the asphalt, which is a decided advantage, but more criticism is made as to slipperiness of the tarred surfaces during freezing weather. It is thought that the tars have the greater adhesive quality, but that the exposed surface due to evaporation of volatile constituents becomes crumbly or dead in a shorter time than a similar grade of Asphalt.

Regarding rate of application per unit area, this will vary with the porosity of the surface to be treated; for the cold, or light hot application ranging between one-sixth and one-third gallon per square yard. Experience is that from one fifth to one quarter gallon will produce good results on the average surface.

Preliminary to the applying of the bituminous material the surface to be treated should be swept clean if necessary, to free it from all loose and organic matter; after this has been done the application can proceed regardless of whether the surface is wet or dry, providing there are no pools of standing water on the surface, a slightly damp surface apparently gives better penetration than an absolutely dry surface, the object sought being to get the material into the texture of the road. The surface treatment should be confined to one side or half width of the road at a time, leaving the other side available for traffic. Some little time should be allowed for proper penetration, but within one hour after the application it should be lightly covered with suitable material. Traffic can now use this side and the treatment continued on the opposite side.

The materials recommended for cover are crushed stone or slag which will pass a half inch mesh and are free from dust, ore tailings, fine screened gravel or coarse sharp sand. The toughness of the mineral aggregate used for oiling cover is an element in the durability of the mat formed by the treatment. Relative cost will determine the selection of material to be used for cover. The quantity of cover necessary will vary with the rate of application of the bituminous material and with the porosity of the surface treated.

Where the rate of application of oil is from one-fifth to one-quarter gallon per square yard the range of cover may be stated as being

between thirty-five and seventy cubic yards per mile of road sixteen feet wide, and generally forty to fifty cubic yards will be ample.

This cover should be uniformly applied either by hand or by mechanical spreader; however, only sufficient to cover the oil lightly should be applied at one time. It will require two or three separate spreadings from time to time as the surface becomes shiny and sticky to produce a perfect mat. Any excess unused material delivered for cover should finally be gathered up and stored in neat piles back of the ditch line where possible. These treatments do not require rolling, although rolling tends to turn any coarse sharp fragments of cover material onto their broader sides, reducing danger of tire cuts to a minimum.

[1] Thick mats formed of binder and three-quarter inch stones while durable are not generally satisfactory; they are expensive, costing from one to two thousand dollars per mile and frequently become rough under traffic, although they do serve at times to carry a road along for a few years which would otherwise be a resurfacing matter. This treatment also is used to restore a crown to a road worn flat.

On gravel and new waterbound macadam and upon roads where there is little motor traffic, maintenance by calcium chloride is effective. Where this treatment is used the applications may be of the granulated crystals applied by hand or by a mechanical spreader, at the rate of one pound to one and a quarter pounds per square yard; preliminary sweeping is not necessary unless there is excessive dust, say a quarter inch depth or more upon the surface proposed to be treated. Should this treatment be made immediately preceding a rain, a considerable quantity of material would be lost. Two or three treatments as above should suffice for the average season, and the width treated may be confined to the width of the traveled way. This treatment has cost in New York State about one hundred fifty dollars a mile a year. Surfaces which have previously been oiled are not recommended for Calcium Chloride treatment.

In cases where, continued surface treatments of Bituminous material through successive years has built up an excessive depth of mat, which has a tendency to be unstable and rut, it is suggested that such mat be removed and spread upon the shoulders, which will cost from fifty to one hundred fifty dollars a mile, and that surface treatments be again made upon the macadam itself. Should it be found that the macadam has become uneven, as to crown and grade, or is badly worn or has numerous holes, it is suggested that the road be scarified and thoroughly dragged with a heavy spike-tooth harrow, after which an agricultural weeder should be repeatedly hauled over the road, the object sought being to work all of the finer particles to the bottom of the scarified course, leaving fairly clean coarse stone at the surface; this should be shaped up by hand or scraper and rolled to develop any irregularities in the surface which should be corrected by the addition of new crushed stone. Any pockets of fine material should be removed and replaced by new top course stone, the weeder should again be used to loosen the stone,

[1] The authors wish to emphasize the danger of using thick mats for ordinary maintenance.

which will then be ready for the first application of binder, which may be at the rate of three-quarters of a gallon per square yard, application being made by a pressure distributor, the surface then to be covered with a layer of three-quarter inch broken stone and thoroughly rolled. During the rolling, additional three-quarter inch stone shall be applied and broomed about until the voids in the top course are well filled; all loose stone shall then be swept from the surface and a sealing coat of one-half gallon of binder per square yard shall be applied and immediately covered with a layer of one-half inch stone and again rolled; surface will then be ready for traffic. This treatment is probably better adapted to waterbound macadam than to the penetration bituminous type; however, if found necessary to break up and reshape penetration macadam, it is suggested that the latter loosening by the weeder be omitted and a spread, one stone thick, of two-inch broken stone be applied and the first application of binder be increased to one gallon or one and a quarter gallons. This method is not applicable to an extended mileage as it is generally better to resurface when a road reaches this stage.

Concrete Roads with Thin Bituminous Surfaces.

The second-class concrete with thin bituminous wearing surface is a difficult type to maintain; the bituminous surface under traffic patches off, and as the concrete is usually not strong enough to resist abrasion, holes develop in the concrete, patching results in a rough riding surface and probably the best way to secure a smooth riding road is to resurface, using a two-inch bituminous mixing type top.

Asphalt, Topeka Mix, Amiesite, etc.

The holes which develop in the bituminous mixing method type wearing surfaces should be repaired as follows: — Excavate the old material at the defective spot the entire depth of course, so that the edges will present clean, vertical surfaces, these surfaces and the exposed foundation to be swabbed or painted with hot asphaltic cement or paving pitch, the hole then to be filled, with a mixture similar to that used in original construction, whenever practicable, using sufficient quantity so that after consolidation by rolling (or tamping in case the extent of repairs is limited) the surface of the new patch will be flush with the adjacent pavement. In case there is no local mixing plant available, or the limited extent of repairs do not justify expense of treatment as above, holes may be repaired with the mixture of crushed stone and cold patch asphaltic emulsion, as outlined for macadam surfaces.

Concrete Pavements.

The cracks which develop in concrete pavements may be the result of either frost action, settlement of foundation or contraction, and are properly treated by being poured with hot paving pitch or asphalt binder. If spots disintegrate, the defective material should be removed and replaced by new concrete.

Block Pavements.

Block pavements of brick, stone, asphalt, etc. properly constructed should not require repairing for a considerable term of years; cracks which develop should be grouted with hot paving pitch or asphalt binder; areas which settle, thereby breaking the bond of the grouted joints resulting in crushing or cobbling the blocks, should be taken up, the sand cushion reformed, all sound blocks cleaned and re-laid, being turned over where necessary, any broken blocks to be replaced by new whole ones, joints then to be grouted with Portland cement grout preferably, if the original pavement was so constructed, otherwise the joints may be poured with hot paving pitch. It should be noted that repairs with fresh cement grout require to be protected by barricades for a period of about a week, so that such repairs should be confined to one side of the pavement in long stretches, leaving the other side available for traffic; where the repairs are limited in extent and barricades are especially undesirable, the patch may be covered with two inches of earth and further protected by planking during the time required for the grout to set. Where joints are poured with paving pitch, traffic need be diverted only during the time of actually making the repair; this is a decided advantage.

Observation demonstrates that horse traffic on steep grades leave the pavement and seek the earth shoulder, so that so far as practicable these shoulders should be improved by widening, and by gravelling or covering with broken stone to avoid excessive rutting, also that on sharp curves the tendency of motor vehicles is to cut close to the inner edge, making it well for this reason to stone or gravel the shoulders at these points.

Along the edges of the rigid types of pavement, block and concrete especially, traffic usually develops a deep rut which if neglected becomes dangerous, to rapidly moving traffic; this rut should be kept filled with gravel or broken stone. Excess material when removed from the shoulders should be so disposed of as to widen embankments and flatten slopes.

General Organization Methods.

There are three general plans for performing the work of general maintenance: the patrol system, the repair gang and by contract. The nature of the work renders it difficult to estimate in terms of labor and material with precision, so that except in the case of surface treatments, repair by contract is not advised. By the patrol system the roads patrolled are under constant supervision and the responsibility for neglect is fixed. The repair gang may be used to supplement the patrol system when it is desired to expedite extensive small repairs, and also to perform all necessary repairs upon any roads not patrolled. A patrolman living in the vicinity of his work, equipped with a single horse, one yard wagon and small tools, costing three dollars a day, can make all minor repairs on a section of between five and seven miles of macadam. The repair gang should be equipped with a small motor truck, say of one and a half tons capacity, to be used in transporting the men and tools within

a radius of about twenty-five miles from their headquarters base; this truck can also assist by hauling some materials required in the work.

It is concluded that a combination of the patrol and repair gang systems is an improvement over the adoption of either plan of organization exclusively, also that the success of either plan depends entirely upon the experience, good judgment and ability of the man in direct charge and control of this work. As nearly all of the hauling in connection with maintenance work is over hard-surfaced roads, motor equipment for delivering stone, oil, etc. would naturally be considered. The writers' opinion is that for short hauls teams are economical, also that the motor tractor and trailers system of equipment are more efficient than the complete single unit system.

Summarized Costs for the Season of 1915 New York State.

In order that the following figures may be more easily understood, it is well to outline the development of the use of the different types of pavement.

From 1898 when State Highway Improvement began until 1909 to which time 1787 miles had been constructed, practically the entire mileage consisted of Waterbound Macadam. Up to this time there had been no systematic maintenance, which resulted in a large mileage of road requiring more than ordinary expenditure to bring it up to standard.

Beginning in 1909, Penetration Bituminous Macadam was generally used on the main roads with Brick near cities and villages.

About 1912 the department tried out Concrete roads with thin Bituminous Oil Tops. This type proved unsatisfactory in that the bituminous surface peeled in spots and the concrete used was not sufficiently strong to stand the traffic directly. The high cost of maintenance can be seen from the following table. The type has not been used since 1914. The department is now designing first-class Concrete roads where roads of that class are economical.

In the following tabulation of maintenance and renewal costs, therefore, the average per mile represents approximately a fair sample of both yearly maintenance and renewal for Waterbound Macadam, Gravel and Concrete Bituminous and represents only ordinary yearly maintenance for Bituminous Macadam, Concrete Pavements, Brick and other high-class rigid pavements; none of these latter classes have been down long enough to yet require renewal, which makes their cost as shown much less than will ultimately be required.

[1] TABLE SHOWING MAINTENANCE AND RENEWAL COSTS IN 1915

Type of Road	No. Miles	% of Total Mileage	Total Cost	Cost per Mile Maintenance and Renewal	Cost per Mile Ordinary Maintenance	Cost per Mile of Renewals distributed over Total Mileage of Each Type (see next table)
Gravel	193	3	$ 183,921.50	$ 955	$555	$400
Waterbound Mac.	2,298	41	2,415,726.84	1,051	551	500
Penetration Bit. Mac.	2,387	43	1,217,059.84	510	410	100
Mixed " "	63	1	11,399.36	181	180	—
Concrete Bit. Surface Coat	295	5	309,589.53	1,049	500	550
1st Class Concrete Pav.	84	2	10,867.80	129	130	—
Block Pavements	291	5	55,253.22	190	170	—
Totals and Averages	5,611	100	$4,203,818.09	$ 750	480	—

[1] Costs include all engineering and overhead administrative charges.

Of the mileage shown in the preceding table, the following table shows the amount of resurfacing.

[1] TABLE SHOWING RESURFACING COSTS 1915

Type of Road Resurfaced	No. Miles	Total Cost	Cost per Mile
Gravel	12.88	$ 77,686.27	$6,000
Waterbound Macadam	176.29	997,776.66	6,000
Penetration Bituminous	43.72	243,760.22	6,000
Concrete Bituminous Top	24.85	160,321.37	6,400
Block Pavements	0.36	4,003.40	12,000
Totals	258.10	$1,483,547.92	

[1] The type of resurfacing is not necessarily the same type as the original road as shown in column No. 1.

Supplementary Explanation of Mr. Bristow's General Costs and Discussion

The authors wish to call attention to two points in the general cost tabulation. The average cost of maintenance and renewal for 1915 is given as $750 per mile for the total system. This system includes approximately 1,000 miles of road recently built on which there is practically no charge except minor repair aggregating not over $200 per mile per year. For a completed system of this character all of which is under normal maintenance and renewal, the average cost per mile would be approximately $900 per mile, as is evident by excluding the thousand miles from the tabulation of total cost.

In the resurfacing table it is evident from the cost per mile that better grades of top courses were generally placed on the Waterbound and Gravel roads than originally constructed; this means that in some cases the original design was not proper for the class of traffic the road served.

The most evident faults of the usual maintenance are in delaying the work till late in the season and in careless mending of ruts and depressions before the application of surface treatments. It is well to emphasize the necessity of using a coarse grade of stone preferably $1\frac{1}{2}$ to $2\frac{1}{2}''$ size in mending noticeable depressions. The hole should be dug out, the edges squared up, the depression filled, bound with heavy binder and screened and rolled. Carelessness in this regard has resulted in a large amount of justifiable complaint.

Typical Maintenance Costs of Different Types.

From a detailed study of 600 miles of road in Western New York with which we are personally familiar, the following typical costs are derived.

It is assumed that the type used is suitable to the class of traffic served as indicated on page 96.

The maintenance system is a combination of patrol, gang work and contract. A one-man patrol with horse and wagon is used to keep the shoulders in shape, the ditches clean and small holes repaired. Gang work with proper machinery under state control to paint guard rail and make more extensive surface repairs and contract work for oiling and surfacing. Detail oiling costs are given under cost data, (page 333). This system is not highly efficient as the executive heads are changed at short intervals for partisan reasons; the department is a convenient means of dispensing minor patronage and the maintenance money is rarely available early enough in the spring to be used to the best advantage, but it represents about as good a method as can be expected in doing public work on a large scale and as such is of more practical value as a guide of costs than figures based on maximum efficiency.

16′ Waterbound Macadam Class II and III Traffic.

Life of Top Course 4 to 10 years. Say 6 years for Class II Traffic and 8 years Class III Traffic under the following maintenance.

Class II Traffic.

Yearly patrol including materials for Minor Repairs and Painting Guard Rail @ $200 per mile per year	$1,200
Calcium Chloride 1st and 7th year @ $125 per mile per year	250
Cold Oiling 2nd year	250
" " 3rd "	300
" " 4th "	300
Hot Oiling 5th "	1,000
Cold Oiling 6th "	250
Resurfacing with Waterbound Mac. 7th year	4,000
7 year total	$7,550

Cost per mile per year Maintenance and Renewal....$1,000
" " " " " for Maintenance..............500

Class III Traffic.

Yearly Patrol	$1,600
Calcium Chloride 1st and 9th years @ $125 per year	250
Cold Oil 2nd year	250
" " 3rd "	250
" " 4th "	300
" " 5th "	300
Hot Oil 6th "	1,000
Cold Oil 8th "	250
Resurfacing 9th "	4,000
9 year total	$8,200

Cost per mile per year Maintenance and Renewal.....$900
" " " " " for Maintenance...............500

16′ Penetration Bituminous Macadam, Class II and IV Traffic.

Life of Top course 5 to 10 years. Say 8 year average.

Yearly patrol @ $150 per mile per year	$1,200
Cold Oil 3rd year	250
" " 4th "	250
" " 5th "	300
Hot Oil 6th "	1,000
Cold " 8th "	250
Resurfacing 9th year Bit. Mac.	6,000
9 year total	$ 9,250

Cost maintenance and renewal per mile per year.....$1,000
" " per mile per year..................400

16′ Brick Pavement, Class I Traffic.

Probable life based on Medium Traffic Rochester City Streets 10 to 25 years. Say 18 year average.

Yearly patrol and minor repairs @ $150 per mile per year	$2,700
Renewal of surface and edging	15,000
18 year total	$17,700

Cost of maintenance and renewal per mile per year..$1,000
" " " per mile per year approx....... 200

16′ 1st Class Concrete Pavement, Class II A Traffic.

None of these pavements have been down a sufficient length of time to give us any reliable data as to probable length of life before resurfacing. We will assume 10 to 15 years or an average of 12 years when they will be resurfaced with Asphalt, Brick, or Clay Cubes at a cost of $9,000 to $15,000 per mile.

Yearly patrol $150 per mile per year	$1,800
Resurfacing and minor renewals	10,000
13 year total	$11,800

Cost of maintenance and renewal per mile per year....$900
" " " per mile per year approx.........$200

Maintenance Conclusion.

The indications are that the yearly cost of maintenance and renewal of a well-designed road system will run about $900 per mile per year. The effect of bad design is evident from resurfacing costs, for if Waterbound Macadam is built on a Class I Traffic Road the life is easily halved, increasing the maintenance and renewal cost to $1,500 per mile per year and causing continual inconvenience to the traveling public by repairs and reconstruction.

Probably the most feasible method of reducing maintenance cost will be by utilizing Prison labor to manufacture and in a limited way apply the maintenance materials.

Summary Showing Approximate Yearly Cost per Mile of Different Roads

Type	Class of Traffic	First Cost per mi.	4% yearly Interest on 1st Cost	Yearly Maintenance	Cost of Resurfacing Distributed Over Life of Road on Yearly Basis	Total Cost per mi. per year
Brick 16′	I	$25,000	$1,000	$200	$800	$2,000
Concrete Pav. 16′	IIA and IV	15,000	600	200	700	1,500
Penetration Bit. Mac. 16′	II and IV	13,000	520	400	600	1,520
Waterbound Mac. 16′	II	11,000	440	500	500	1,440
Waterbound Mac. 12′	III	9,500	380	400	400	1,180

CHAPTER VI

MINOR POINTS

UNDER this heading are included guard-rail, bridge-rail, retaining walls, toe walls, curbs, guide and danger signs, cobble gutters, rip-rap, catch-basins, grates, and dykes.

Guard Rail (Wooden).

The construction generally used is shown in the following sketch:

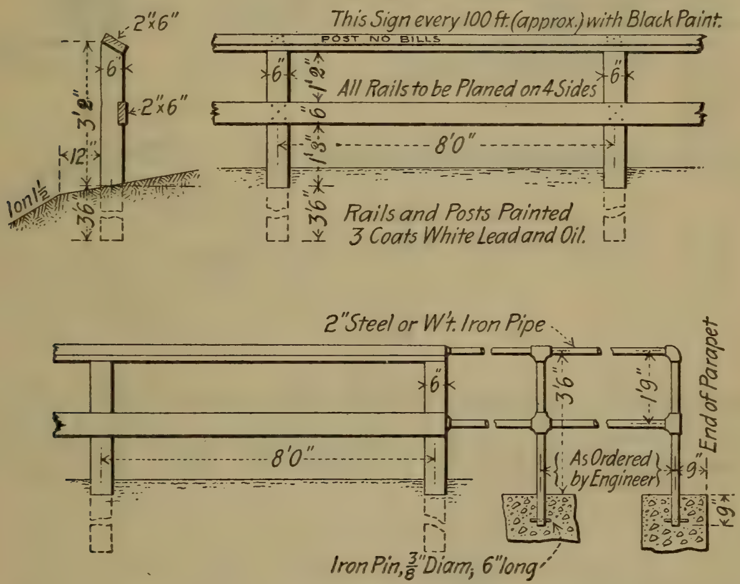


FIG. 29

The posts are cedar, white oak, or chestnut, and the rails are hemlock, yellow pine, or white pine. Such guard-rail costs from twenty-five to forty cents per foot, about five cents per foot per year for maintenance, and needs renewal every eight to ten years: the capitalized cost at 4% is approximately $1.25 as figured by the New York State Highway Commission, and on this basis they have decided that it is cheaper to use a fill slope of 1 on 4 up to a seven-foot depth, eliminating the guard-rail, than it is to use a 1 on 1½ fill slope with guard-rail.

The wooden guard-rail as built acts as a warning only. If a machine or rig becomes unmanageable and hits the rail, it generally breaks or the posts tear out, allowing the vehicle to turn turtle on the fill

slope. So many accidents of this kind occur that there is a demand for a rail that actually gives protection as well as a warning.

Concrete Guard-Rail.

Because of this demand and the high cost of maintenance and renewal of the common wooden rail, concrete guard-rail is being adopted. The simplest and best design of this kind that the author has seen was tried out by the New York State Department of Highways on the Ridge Road, near Rochester, N.Y., in 1910. A sketch is given below. This construction has been specially commended by the automobile associations.

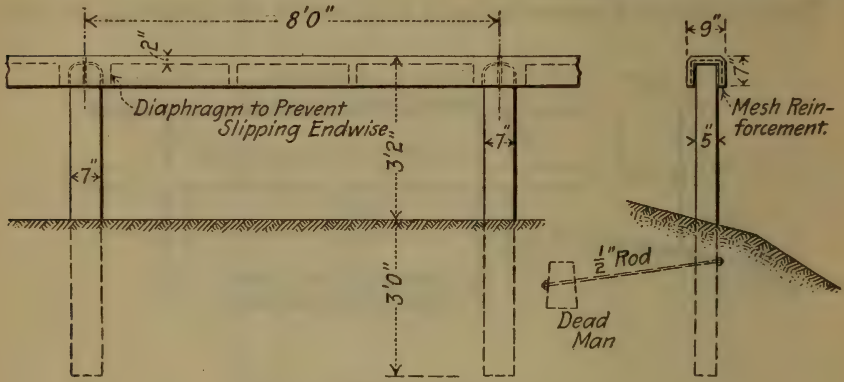


FIG. 30

The rail was invented by J. Y. McClintock, County Engineer of Monroe County, N.Y. It is neat in appearance, durable and strong, and is specially adapted for a combination bridge and approach

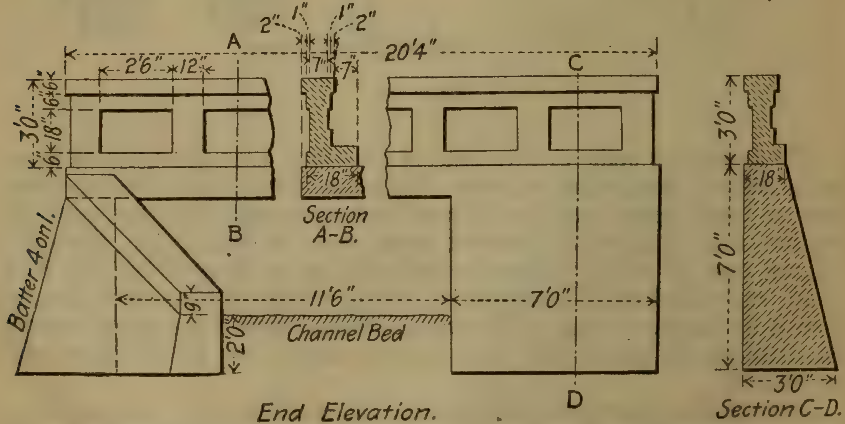
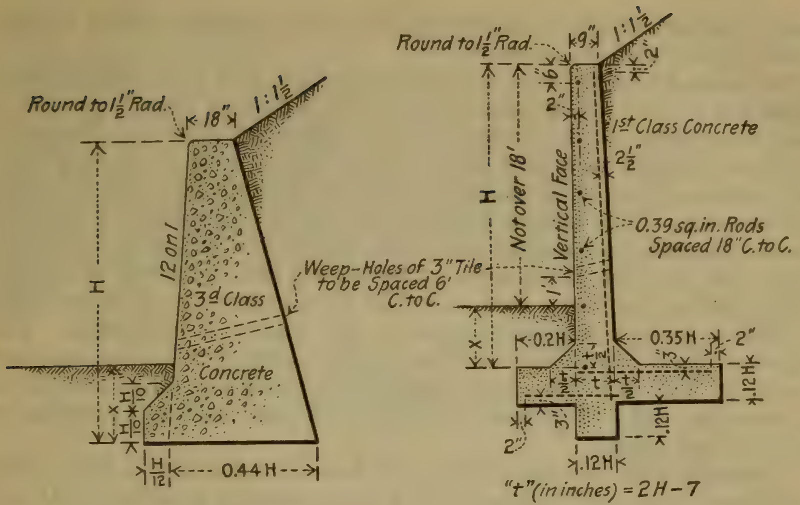


FIG. 31. — Showing Raised Parapet on Skew Bridge extended over Straight Parapet Retaining Wall



Type W. Type R.

FIG. 32.— New York State Standard Retaining Walls

H	Reinforcing Steel Bars of Deformed Section								
	Stem[1]			Heel			Toe		
	Net Area	Spacing C–C	Length	Net Area	Spacing C–C	Length	Net Area	Spacing C–C	Length
11′	0.601	6¼″	12′–2″	0.442	7½″	4′–11½″	0.442	9½″	3′–3½″
12′	0.601	5½″	13′–3½″	0.442	6¼″	5′–5½″	0.442	8¼″	3–8″
13′	0.601	5″	14′–5″	0.442	5¼″	6′–0″	0.442	7¼″	4′–0½″
14′	0.601	4½″	15′–6½″	0.601	6¼″	6′–6″	0.601	8½″	4′–4½″
15′	0.601	4″	16′–8″	0.601	5⅜″	7′–0″	0.601	7⅜″	4′–9″
16′	0.994	6″	17′–9″	0.601	4¾″	7′–6½″	0.601	6½″	5′–1½″
17′	0.994	5½″	18′–10½″	0.785	5½″	8′–0½″	0.785	7⅝″	5′–6″
18′	0.994	5″	20′–0″	0.785	4⅞″	8′–7″	0.785	6⅞″	5′–10½″
19′	0.994	4½″	21′–1½″	0.785	4⅜″	9′–1″	0.785	6¼″	6′–2½″
20′	0.994	4⅛″	22′–3″	0.785	4″	9′–7″	0.785	5¾″	6′–7″

[1] In each set of 3 bars in stem, first bar which is of length given, extends to top of wall, second bar to height $\frac{2}{3}$ H, third bar to height $\frac{1}{3}$ H.

When Type W is used as a bank wall (that is, above the roadway), max. H = 20′; min. X = 2′ for H of 5 to 10′; and 0.2 H for H greater than 10′.

When Type W is used as a sustaining wall (that is, below the roadway), max. H = 13′; and min. X = 3′, except where foundation is rock or entirely below frost.

When Type R is used as a bank wall, max. H = 20′; min. X = 0.15 H for H greater than 10′.

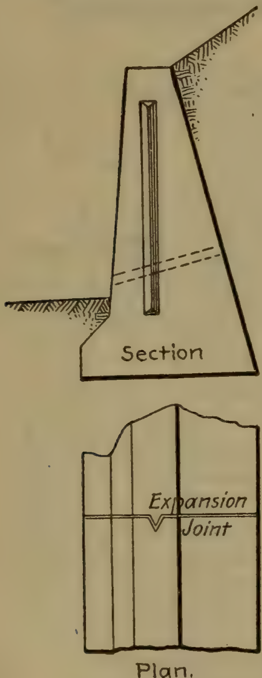
When Type R is used as a sustaining wall, max. H = 13′; min. X = 0.25 H for H greater than 10′.

rail. The old design of an iron bridge rail connected with a wooden road rail has been an eyesore.

The actual cost of manufacture and setting was from fifty to sixty cents per foot. The contract price for such rail would, probably, run from eighty cents to one dollar, depending upon the length of the haul, freight rate, and difficulty of digging post holes, but even at the high figure it is cheaper than the wooden rail and is a safe construction. The anchor and rod shown on the sketch is used on curves or even on straight stretches where new fill is encountered, to prevent the posts being torn out by impact from runaway machines.

The rail proper has a web and bar reinforcement; it is designed to stand a six-ton horizontal load at the center of the panel. The rails and posts are molded separately and allowed to set for, at least, a month; they are then put together in much the same manner as the wooden rail. The rounded top of the post makes it possible to erect on any grade.

A considerable mileage of this rail has been erected in New York and New Jersey and has prevented many serious accidents. It has been hit by autos, tar kettles, rollers, traction-engines and rigs and in no case has the vehicle gone over the bank — which is the general cause of fatal accidents. The rails and posts will break when hit by a heavy machine, but the reinforcement merely bends (does not snap) and continues to exert enough resistance to hold the machine on the roadway.



Key Expansion Joint.

FIG. 32 A

Guard Rail has two distinct purposes: first, as merely a warning, at culverts, curves, low embankments, etc. where the danger is not great, and second, as an actual protection in dangerous places. Concrete guard rail is not advocated where warning alone is sufficient.

Bridge Rail and Raised Parapets.

Bridge rail for small span bridges is of two types, iron pipe rail (see figure 29) or solid raised parapets (see figure 31). The solid parapet is to be preferred.

Retaining Walls.

In unusual cases retaining walls are needed in road construction. Plain or reinforced concrete walls are generally used, the selection depending upon the relative cost. The plain concrete wall is considered the best type for heights up to twelve feet; the reinforced cantilever form from twelve feet to eighteen feet, and above eighteen feet the buttressed design. We give page 111 examples and rules for the plain and reinforced cantilever types only, as the necessity for walls higher than eighteen feet is very rare. For the

design of buttressed walls the reader is referred to the standard works on reinforced concrete.

Retaining walls are usually built in monolithic sections of 20′ to 25′ in length; expansion joints are provided between these sections. The expansion joints may consist of simply a plane of weakness between the sections produced by allowing one section to set before building the adjacent wall, or it may be a key joint as shown in figure 32A, and the plane of separation may be made more pronounced by coating the concrete with a thin layer of asphaltum or pitch.

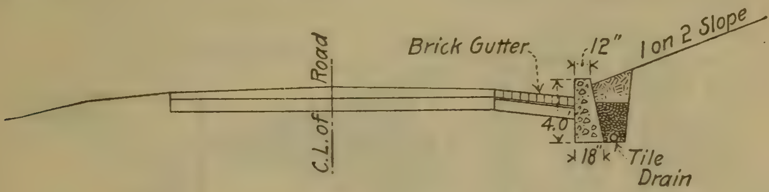


FIG. 33. — Showing Concrete Toe Wall

Toe Walls.

Toe walls are nothing more than low retaining walls or very substantial curbs. They are used in cuts on the outside of the gutters to prevent unstable side slopes from filling the gutters or heaving them out of shape by sliding pressure. Figure 33 gives a section of Eden Valley Hill near Buffalo, N. Y., where a clay quicksand cut was successfully protected in this manner.

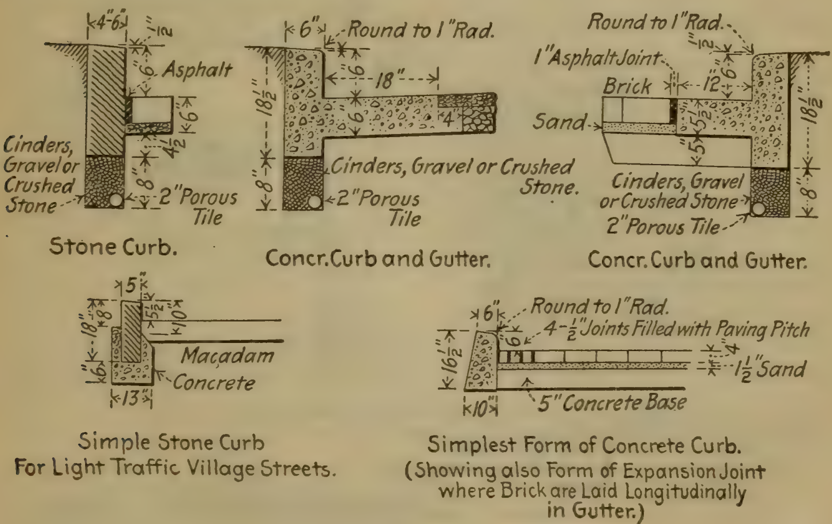


FIG. 34

Curbs.

Curbs are constructed of stone and of concrete.

Stone Curbs.

The cuts given show the methods of setting; the size of curbstones for first-class work range from 16″ to 22″ in depth, 5″ to 6″ in thickness and 3′ to 5′ in length. For small villages, curbstone of 4″ width, set in the simplest manner shown, is satisfactory. The stones most used are granites, bluestones of New York State, and the tougher sandstones such as Medina, Berea, Kettle River, etc. The prices range widely, depending on the locality of the work. Mr. William Pierson Judson, in his "Roads and Pavements," gives the following range of costs:

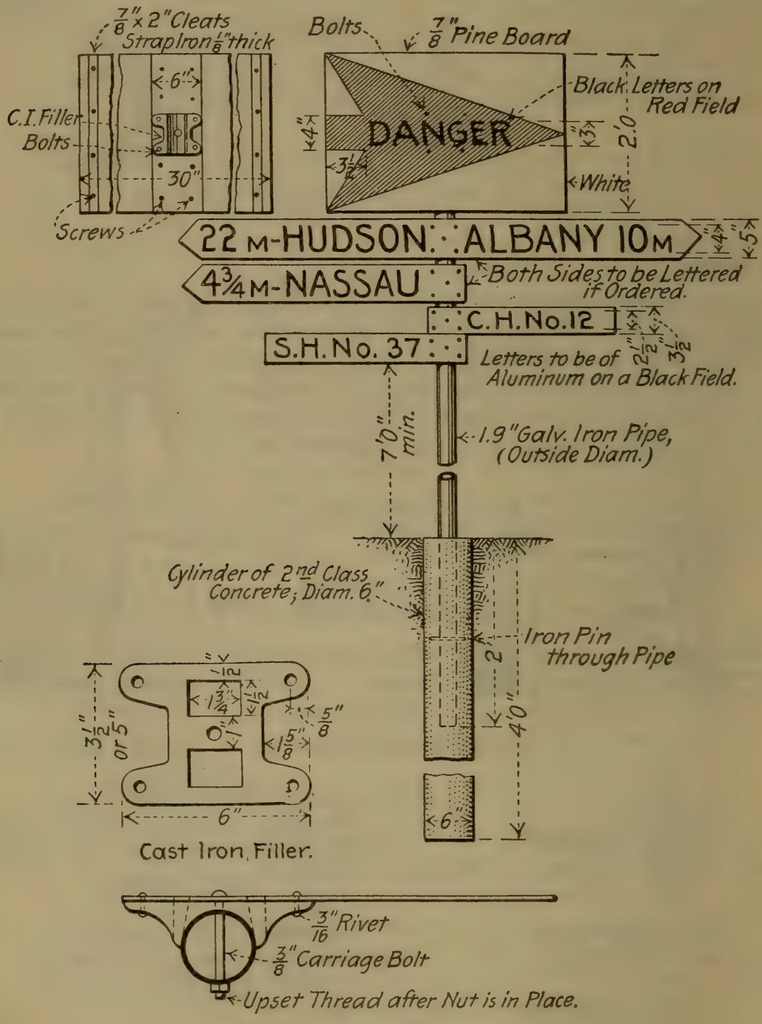


FIG. 35

Straight curbs set, cost about as follows, with 30 per cent to 50 per cent added for curves:

Granite \$0.50 to \$0.90, unusual case \$1.25 per foot.

Ulster and Oxford bluestone, \$0.40 to \$0.80, unusual case \$1.00 per foot.

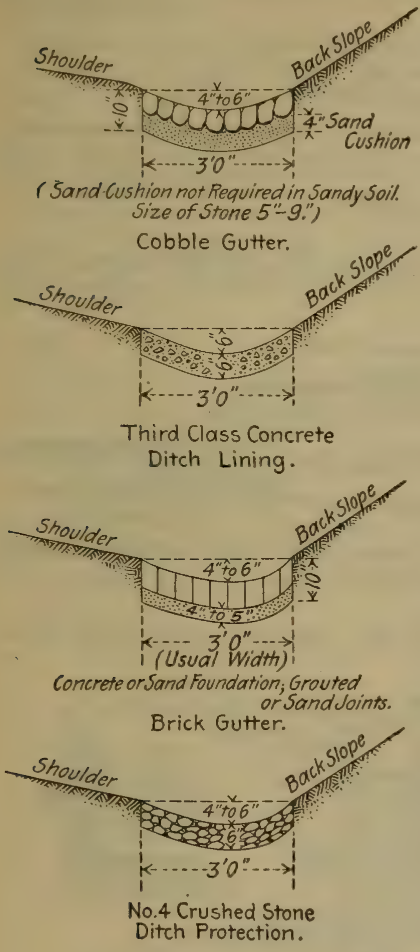


FIG. 36

Medina and Berea sandstone, \$0.35 to \$0.90.

Concrete usually costs from \$.040 to \$0.50 with \$0.35 added for a combined gutter, though combined gutter and curb have been built for \$0.50.

The simple concrete curb (figure No. 34) has been built during 1911 in different parts of Western New York at a cost of \$0.30 to \$0.40 per foot.

Where stone curbs can be built for less than \$0.70 per foot, it seems good policy to use them through the business sections of small villages. For the residential portions or where the cost of stone curbing is high, a concrete curb of the simplest design is the best practice, as city conditions and requirements are neither necessary nor expected.

Guide Signs and Danger Signs.

A good sign must be easy to read, pleasing in appearance and permanent. The drawing shows one of the designs in use; the posts are of galvanized iron and cost about \$5.00 in place; the background for the aluminum is a japanned metal; the signs cost approximately \$0.15 per letter including the board.

Danger signs should be used only where no doubt exists as to their necessity, as their indiscriminate use decreases their effectiveness.

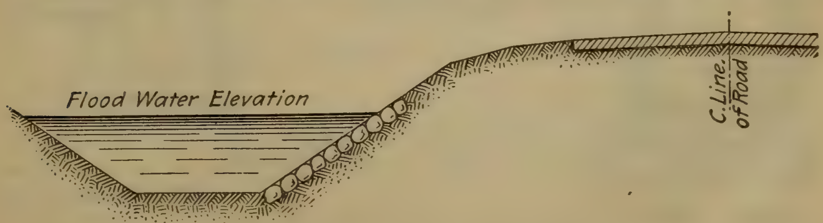


FIG. 37

Cobble Gutters, Brick Gutters, Ditch Linings, etc.

Cobble gutters are used to protect the ditches from wash on steep grades and at entrances to intersecting roads where there is not suffi-

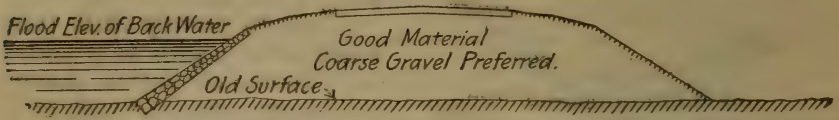


FIG. 38. — Method of Protection where Road can be built above Flood Level

cient headroom for a culvert. Also at the entrances to private property where the grade line of the ditch might be badly cut by vehicles.

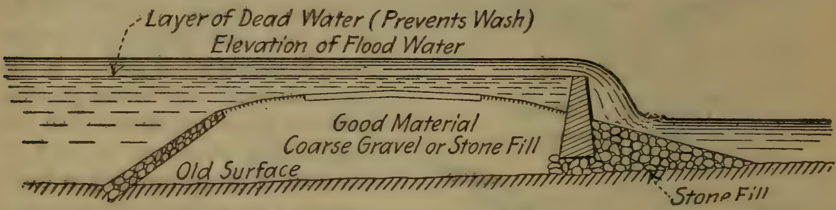


FIG. 39. — Method of Protection where Road cannot be raised above Flood Level

The usual cost of such construction ranges from $0.40 to $1.00 per square yard.

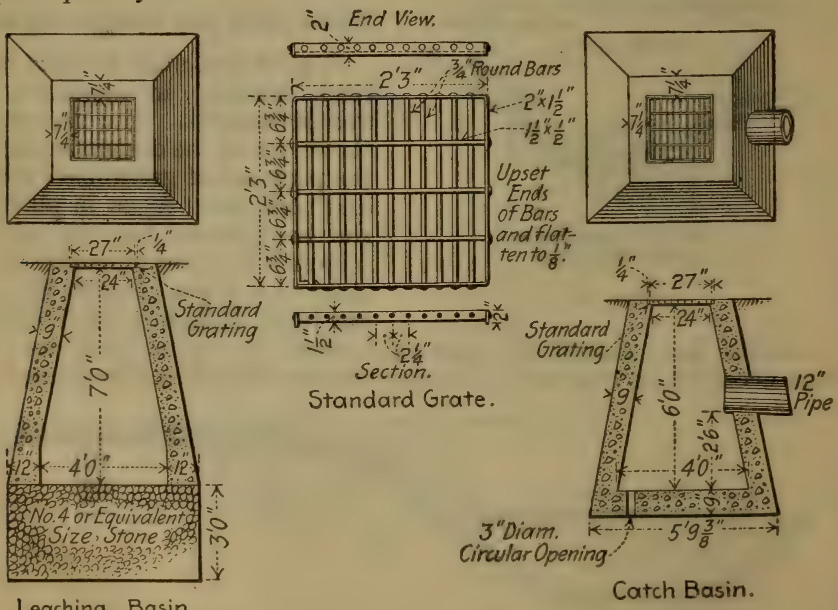


FIG. 40

Where cobblestones are not available, ordinary building brick may be used or No. 4 crushed stone, as shown page 115.

Riprap and Dykes.

Well-constructed riprap protects stream banks and bridge approaches from stream wash except in unusual cases where a solid masonry or concrete protection is required.

The sizes of stone suitable for riprap are usually specified at a minimum of ½ cubic foot and 50 per cent or more of the material to be over 2 cubic feet.

Where the road is located in bottom land and is covered with backwater in the Spring, it can be protected by riprap paving on both sides or a dyke and riprap paving on one side as shown in figures No. 38 and No. 39.

Grates.

Cost of cast-iron grates about $0.05 per pound.
Cost of wrought-iron grates about $0.08 per pound.

Repointing Masonry and Refacing Old Walls.

Old masonry structures can often be used complete or in part by repointing the joints; they should be cleaned out thoroughly with a chisel and filled flush with a 1 to 1 Portland Cement mortar.

The author does not believe in facing up old masonry abutments

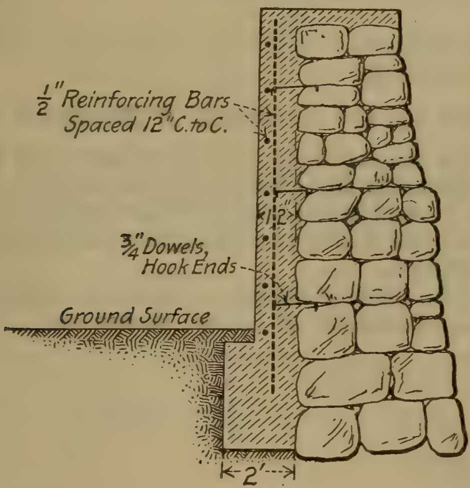


FIG. 41. — Facing for Old Masonry

if it can be avoided; however, if it seems advisable, because of shortage of funds, the old joints should be well cleaned out and hook dowels used as shown in cut No. 41. One dowel every 6 square feet is good practice.

The concrete facing should be at least 12 inches thick and reinforced to prevent settlement and temperature cracks.

CHAPTER VII

MATERIALS

The selection of materials is an important part of the design. Most municipal and State Departments have well equipped laboratories for testing stone, gravels, brick, bitumens, cements, etc. The object of these tests is to determine the physical and chemical properties that have a particular bearing on the action of the materials under construction conditions. While these conditions are not attained they are approximated and by a comparison of the laboratory results with the actual performance of the different materials in practice a relation can be established that is useful as a basis for judgment:

We are greatly indebted in this 2nd edition to Mr. H. S. Mattimore and Mr. J. E. Myers who have rearranged and brought up to date much of the material on tests and their significance.

This chapter gives a brief statement of the desirable qualities and the tests for:

1. Top course, macadam stone.
2. Screenings.
3. Bottom course, macadam stone.
4. Bottom course and sub-base fillers.
5. Brick.
6. Bituminous binders.
7. Concrete materials.

1. Stone for the Surfacing of Macadam Roads

Stone for use in the surfacing of a macadam road should be hard and tough to withstand the abrasive action of team traffic and the vibratory action of high-speed motor vehicles and should not contain any minerals that are likely to disintegrate rapidly under influence of weather conditions.

To determine the relative hardness, toughness and power to resist abrasive and impact action of traffic, stones are subjected to the following tests:

1. Abrasion.
2. Hardness.
3. Toughness.
4. Specific Gravity.
5. Absorption.
6. Fracture.
7. Geological classification.

[1] Abrasion Test.

The machine shall consist of one or more hollow iron cylinders; closed at one end and furnished with a tightly fitting iron cover at

[1] American Society of Testing Materials.

the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth, inside. These cylinders are to be mounted on a shaft at an angle of 30 deg. with the axis of rotation of the shaft.

At least 30 lb. of coarsely broken stone shall be available for a test. The rock to be tested shall be broken in pieces as nearly uniform in size as possible, and as nearly 50 pieces as possible shall constitute a test sample. The total weight of rock in a test shall be within 10 g. of 5 kg.

All test pieces shall be washed and thoroughly dried before weighing. Ten thousand revolutions, at the rate of between 30 and 33 per minute, shall constitute a test. Only the percentage of materials worn off which will pass through a 0.16 cm. ($\frac{1}{16}$ in.) mesh sieve shall be considered in determining the amount of wear. This may be expressed either as the percentage of the 5 kg. used in the test, or the French coefficient, which is in more general use, may be given; that is, coefficient of wear $= 20 \times \frac{20}{w} = \frac{400}{w}$, where w is the weight in grams of the detritus under 0.16 cm. ($\frac{1}{16}$ in.) in size per kilogram of rock used.

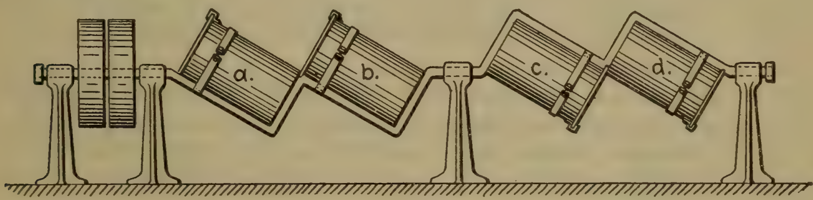


FIG. 42. Deval Rattler

Hardness.

Hardness is determined by a Dorry machine. A stone cylinder 25 cm. in diameter, obtained by a diamond core drill from the material to be tested, is weighed and placed in the machine so that one end rests on a horizontal cast-iron grinding disk with a pressure of 25 grams per sq. cm. The disk is revolved 1,000 times during which standard crushed quartz sand about $1\frac{1}{2}$ mm. in diameter is automatically fed to it. The cylinder is then removed and weighed and the coefficient of hardness obtained by the formula $20 - \frac{1}{3}$ the loss in weight, expressed in grams. In order to get reliable results two cylinders are generally used, each one being reversed end for end during the test.

[1] **Test for Toughness.**

1. Test pieces may be either cylinders or cubes, 25 mm. in diameter and 25 mm. in height, cut perpendicular to the cleavage of the rock. Cylinders are recommended as they are cheaper and more easily made.

2. The testing machine shall consist of an anvil of 50 kg. weight, and placed on a concrete foundation. The hammer shall be of 2 kg.

[1] American Society of Testing Materials.

weight, and dropped upon an intervening plunger of 1 kg. weight, which rests on the test piece. The lower or bear-surface of this plunger shall be of spherical shape having a radius of 1 cm. This plunger shall be made of hardened steel, and pressed firmly upon the test piece by suitable springs. The test piece shall be adjusted, so that the center of its upper surface is tangent to the spherical end of the plunger.

3. The test shall consist of a 1 cm. fall of the hammer for the first blow, and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows necessary to destroy the test piece is used to represent the toughness, or the centimeter-grams of energy applied may be used.

[1] Determination of the Apparent Specific Gravity of Rock.

The apparent specific gravity of rock shall be determined by the following method: First, a sample weighing between 29 and 31 g. and approximately cubical in shape shall be dried in a closed oven for 1 hour at a temperature of 110 degrees C. (230 degrees F.) and then cooled in a desiccator for 1 hour; second, the sample shall be rapidly weighed in air; third, trial weighings in air and in water of another sample of approximately the same size shall be made in order to determine the approximate loss in weight on immersion; fourth, after the balances shall have been set at the calculated weight, the first sample shall be weighed as quickly as practicable in distilled water having a temperature of 25 degrees C. (77 degrees F.); fifth, the apparent specific gravity of the sample shall be calculated by the following formula:

Apparent specific gravity $= \dfrac{W}{W - W_1}$ in which W = the weight in grams of the sample in air and W_1 = the weight in grams of the sample in water just after immersion.

Finally, the apparent specific gravity of the rock shall be the average of three determinations, made on three different samples according to the method above described.

[2] Determination of the Absorption of Water per Cubic Foot of Rock.

The absorption of water per cubic foot of rock shall be determined by the following method: First, a sample weighing between 29 and 31 g. and approximately cubical in shape shall be dried in a closed oven for 1 hour at a temperature of 110 degrees C. (230 F.) and then cooled in a desiccator for 1 hour; second, the sample shall be rapidly weighed in air; third, trial weighings in air and in water of another sample of approximately the same size shall be made in order to determine the approximate loss in weight on immersion; fourth, after the balances shall have been set at the calculated weight, the first sample shall be weighed as quickly as possible in distilled water having a temperature of 25 degrees C. (77 degrees F.); fifth, allow

[1] American Society of Testing Materials.
[2] American Society of Testing Materials.

the sample to remain 48 hours in distilled water maintained as nearly as practicable at 25 degrees C. (77 degrees F.) at the termination of which time bring the water to exactly this temperature and weigh the sample while immersed in it; sixth, the number of pounds of water absorbed per cubic foot of the sample shall be calculated by the following formula:

$$\text{Pounds of water absorbed per cubic foot} = \frac{W2 - W1}{W - W1} \times 62.24$$

in which W = the weight in grams of sample in air, W1 = the weight in grams of sample in water just after immersion, W2 = the weight in grams of sample in water after 48 hours' immersion, and 62.24 = the weight in pounds of a cubic foot of distilled water having a temperature of 25 degrees C. (77 degrees F.).

Finally, the absorption of water per cubic foot of the rock, in pounds, shall be the average of three determinations made on three different samples according to the method above described.

Fracture.

Stone suitable for road work should crush in cubical shapes rather than in thin, flat pieces and preferably with rough, jagged fracture that it may interlock firmly under action of the roller.

Geological Classification.

The geological classification is determined from an examination with a microscope or powerful hand glass, and a consideration of its origin. Great refinements are avoided as the general classification is all that is necessary to the highway engineer after the physical qualities are ascertained by test.

Cost of Tests.

The cost of collecting and testing stone as given in the 1909 Report of the New York State Department of Highways is $8.55 per sample.

The following tables show tests on the more common rock:

Table 21. Taken from Bulletin No. 31, United States Office of Public Roads

Rock varieties	Per cent wear	Tough-ness	Hard-ness	Cementing value	Specific gravity
Granite	3.5	15	18.1	20	2.65
Biotite-granite	4.4	10	16.8	17	2.64
Hornblende-granite	2.6	21	18.3	30	2.76
Augite-syenite	2.6	10	18.4	24	2.80
Diorite	2.9	21	18.1	41	2.90
Augite-diorite	2.8	19	17.7	55	2.98
Gabbro	2.8	16	17.9	29	3.00
Peridotite	4.0	12	15.2	28	3.40
Rhyolite	3.7	20	17.8	48	2.60
Andesite	4.7	11	13.7	189	2.50
Fresh basalt	3.3	23	17.1	111	2.90
Altered basalt	5.3	17	15.6	239	2.75
Fresh diabase	2.0	30	18.2	49	3.00
Altered diabase	2.5	24	17.5	156	2.95
Limestone	5.6	10	12.7	60	2.70
Dolomite	5.7	10	14.8	42	2.70
Sandstone	6.9	26	17.4	90	2.55
Feldspathic sandstone	3.3	17	15.3	119	2.70
Calcareous sandstone	7.4	15	8.3	60	2.66
Chert	10.8	15	19.4	27	2.50
Granite-gneiss	3.8	12	17.7	26	2.68
Hornblende-gneiss	3.7	10	17.1	30	3.02
Biotite-gneiss	3.2	19	17.5	41	2.76
Mica-schist	4.4	10	17.8	30	2.80
Biotite-schist	4.0	—	—	16	2.70
Chlorite-schist	4.2	—	—	24	2.90
Hornblende-schist	3.7	21	16.5	53	3.00
Amphibolite	2.9	10	19.0	29	3.00
Slate	4.7	12	11.5	102	2.80
Quartzite	2.9	19	18.4	17	2.70
Feldspathic quartzite	3.2	17	18.3	21	2.70
Pyroxene quartzite	2.3	27	18.6	17	3.00
Eclogite	2.4	31	17.4	21	3.30
Epodosite	3.6	16	16.0	47	3.03

Tables 22 and 23 Combined

From Annual Report N. Y. State Highway Comm. 1914

County	Number of complete tests	Number of partial tests (no core piece)	Weight lbs. per cu. ft.	Water absorbed, lbs. per cu. ft.	French coefficient of abrasion	Hardness	Toughness	Weighted value
Calcareous Sandstone								
Erie	5	...	167	0.65	9.5	12.9	13.4	68
Saratoga	6	...	169	0.31	10.1	15.9	13.8	76
Steuben	4	1	162	1.44	9.4	15.1	13.1	72
Dolomite								
Clinton	6	...	175	0.41	11.9	15.8	12.7	80
Dutchess	4	1	174	0.43	12.4	17.3	11.9	84
Essex	4	...	173	0.42	13.5	16.9	15.8	90
Franklin	4	...	174	0.51	9.5	14.9	12.1	70
Fulton	4	...	176	0.15	11.8	16.1	14.4	82
Herkimer	17	...	173	0.67	8.4	13.1	6.7	58
Monroe	13	2	171	1.07	10.3	14.8	8.2	69
Montgomery	8	...	174	0.39	10.6	14.7	11.3	73
Niagara	11	...	168	1.50	6.5	14.0	7.0	55
Saratoga	8	...	174	0.33	8.6	15.5	9.2	66
St. Lawrence	31	...	174	0.65	10.5	15.7	9.9	73
Washington	6	...	175	0.29	10.7	15.1	10.5	73
Dolomitic Limestone								
Dutchess	8	1	176	0.46	9.0	14.9	10.9	68
Herkimer	4	1	170	0.47	11.3	16.7	8.2	76
Montgomery	8	1	175	0.41	13.0	15.8	12.4	83
Niagara	7	...	166	2.19	9.5	13.1	7.8	63
St. Lawrence	7	...	168	0.38	9.2	16.8	6.8	68
Washington	4	...	175	0.36	13.7	16.1	10.8	84
Wayne	4	...	173	0.59	10.2	15.5	8.7	71
Gabbro								
Essex	46	1	176	0.29	7.6	17.3	6.9	64
Warren	4	...	183	0.37	10.1	17.7	9.8	75
Gneiss								
Clinton	5	...	185	0.27	10.5	17.2	11.3	78
Dutchess	8	1	172	0.58	7.0	17.1	9.1	64
Essex	29	2	176	0.31	8.4	17.1	8.1	68
Franklin	8	...	178	0.50	6.2	16.1	7.8	59
Fulton	12	1	169	0.25	11.1	17.8	11.5	80
Hamilton	11	...	173	0.37	8.2	17.0	5.8	64
Jefferson	26	1	171	0.23	11.1	17.3	12.0	80
Lewis	6	...	167	0.27	9.6	17.9	10.6	75
Orange	7	...	179	0.38	7.1	17.1	6.4	62
Putnam	10	1	172	0.32	8.5	16.6	7.5	66
Saratoga	7	...	180	0.20	10.0	17.0	8.5	72
St. Lawrence	52	...	172	0.27	9.7	17.5	10.2	74
Warren	30	2	173	0.30	7.5	17.3	6.5	64
Washington	4	...	170	0.29	8.5	17.1	10.9	71
Westchester	37	2	171	0.39	8.3	16.9	7.8	67
Granite								
Essex	5	...	171	0.38	7.5	18.0	5.1	64
Franklin	6	...	165	0.31	8.7	17.9	9.4	71
Hamilton	5	...	165	0.36	9.9	18.1	9.0	75
Jefferson	23	1	166	0.23	12.1	18.4	10.1	83
Lewis	8	...	166	0.36	10.9	18.4	9.2	79
Oneida	6	...	166	0.13	10.2	18.9	8.2	77
St. Lawrence	30	...	165	0.25	9.9	18.3	8.1	74
Warren	5	...	165	0.45	7.9	17.9	7.7	67

FROM ANNUAL REPORT N. Y. STATE HIGHWAY COMM. 1914.—*Cont.*

COUNTY	Number of complete tests	Number of partial tests (no core piece)	Weight, lbs. per cu. ft.	Water absorbed, lbs. per cu. ft.	French coefficient of abrasion	Hardness	Toughness	Weighted value
				LIMESTONE				
Albany	13	7	168	0.60	7.9	14.3	6.4	59
Cayuga	34	6	170	0.49	8.8	14.9	7.8	64
Clinton	14	2	170	0.28	8.2	14.1	5.3	58
Columbia	12	...	170	0.28	9.1	15.3	9.2	67
Erie	9	3	167	0.57	8.1	16.6	8.3	66
Fulton	6	1	168	0.21	7.7	15.5	6.5	60
Genesee	6	3	169	0.26	8.0	15.0	8.2	62
Greene	11	...	169	0.36	11.1	16.4	8.9	75
Herkimer	17	9	169	0.26	8.7	14.8	8.2	64
Jefferson	105	44	169	0.28	7.6	15.1	6.4	59
Lewis	26	20	169	0.32	6.9	14.1	6.2	55
Madison	16	1	169	0.23	8.4	14.7	7.7	62
Monroe	4	...	168	0.27	8.1	14.1	7.4	60
Montgomery	12	2	169	0.24	8.5	15.3	8.0	64
Niagara	11	1	168	0.84	7.1	12.8	6.5	53
Oneida	31	19	169	0.29	7.8	13.8	6.6	58
Onondaga	25	1	170	0.38	8.9	15.7	8.4	67
Ontario	11	...	169	0.39	10.2	15.9	10.2	73
Otsego	7	2	169	0.32	8.1	14.1	6.3	59
Rensselaer	4	1	171	0.21	7.5	15.0	5.3	58
Saratoga	5	...	170	0.24	8.7	13.7	7.0	60
Schoharie	29	2	169	0.34	8.1	14.9	6.7	61
Seneca	7	3	169	0.21	9.4	15.3	7.9	67
Ulster	12	3	170	0.25	8.1	15.6	7.4	63
Warren	5	...	170	0.24	8.9	15.7	7.4	66
Washington	5	3	169	0.34	7.9	15.5	6.9	62
				MARBLE				
Dutchess	4	...	178	0.30	7.3	14.2	6.0	56
				QUARTZITE				
Columbia	16	...	168	0.28	16.5	18.3	17.1	103
Dutchess	8	2	166	0.36	13.5	18.8	11.8	90
Rensselaer	10	...	166	0.49	12.1	18.7	14.8	89
Washington	12	...	167	0.40	14.6	18.9	16.3	98
				SANDSTONE				
Allegany	8	...	156	2.10	8.4	13.4	9.1	61
Broome	11	...	165	1.29	7.8	12.9	10.5	60
Cayuga	4	1	167	1.16	7.8	12.1	10.5	58
Chenango	15	1	164	1.58	8.7	11.2	10.4	59
Clinton	14	...	163	0.71	11.7	18.5	11.0	83
Delaware	53	2	167	1.45	7.0	12.7	8.5	55
Erie	8	1	159	2.10	6.3	5.1	7.8	37
Franklin	5	...	157	1.06	9.7	17.9	7.1	72
Greene	6	...	169	0.62	8.6	14.5	8.1	63
Herkimer	4	...	160	2.50	10.9	16.4	10.7	76
Jefferson	8	...	156	1.46	8.3	16.2	6.3	64
Livingston	4	...	160	3.02	8.8	9.6	8.8	54
Madison	5	...	163	2.15	9.9	13.9	8.6	66
Niagara	7	...	158	1.78	9.0	16.4	8.2	68
Orleans	8	...	155	2.18	11.8	14.4	8.1	72
Otsego	21	1	162	1.75	8.4	11.9	9.6	59
Saratoga	5	...	163	0.36	10.7	18.0	8.7	77

FROM ANNUAL REPORT N. Y. STATE HIGHWAY COMM. 1914.—*Cont.*

County	Number of complete tests	Number of partial tests (no core piece)	Weight, lbs. per cu. ft.	Water absorbed, lbs. per cu. ft.	French coefficient of abrasion	Hardness	Toughness	Weighted value
			SANDSTONE.—*Continued*					
Schoharie ...	6	3	165	1.21	9.4	15.2	11.7	70
Schuyler....	4	...	162	2.14	8.1	11.6	10.6	58
Seneca......	5	...	165	0.86	11.0	13.9	15.8	77
Steuben.....	22	3	157	2.79	8.3	9.3	10.0	54
St. Lawrence	16	...	159	0.79	10.0	17.8	7.2	73
Sullivan....	30	4	164	1.26	6.5	14.9	8.2	58
Ulster......	8	...	166	0.64	8.0	14.3	8.1	61
Wyoming...	7	...	159	2.54	6.0	5.1	7.9	36
			SANDY GRIT					
Albany.....	5	...	167	0.75	7.5	13.2	7.2	56
Columbia...	12	...	168	0.32	10.7	15.9	11.7	76
Dutchess....	10	2	168	0.57	8.1	16.2	11.5	68
Greene.....	13	...	169	0.48	7.1	15.6	9.5	62
Montgomery	4	...	166	1.39	10.1	11.3	11.8	65
Rensselaer..	10	...	169	0.44	9.1	15.9	9.4	69
Saratoga....	5	...	168	0.99	11.8	15.2	11.9	78
Schenectady	4	...	165	1.10	9.2	14.6	9.5	66
Ulster......	7	...	169	0.59	7.5	13.8	10.2	60
			SYENITE					
Essex.......	7	...	184	0.52	7.7	17.1	6.7	64
Franklin....	4	...	171	0.45	10.1	18.3	8.0	75
Herkimer...	13	...	174	0.16	12.5	18.0	11.6	85
Jefferson....	7	...	176	0.34	12.4	18.1	14.5	88
			TRAP					
Rockland...	12	...	183	0.39	13.2	17.6	1.64	91

TABLE 24.[1] GEOLOGICAL CLASSIFICATION

Class	Type	Family
I Igneous	1 Intrusive (plutonic)	*a* Granite *b* Syenite *c* Diorite *d* Gabbro *e* Peridotite
	2 Extrusive (volcanic)	*a* Rhyolite *b* Trachyte *c* Andesite *d* Basalt and diabase
II Sedimentary	1 Calcareous	*a* Limestone *b* Dolomite
	2 Siliceous	*a* Shale *b* Sandstone *c* Chert (flint)
III Metamorphic	1 Foliated	*a* Gneiss *b* Schist *c* Amphibolite
	2 Nonfoliated	*a* Slate *b* Quartzite *c* Eclogite *d* Marble

[1] Bulletin No. 31, United States Department of Public Roads.

The following quotation from this same bulletin describes the characteristics of the three groups:

Igneous Rocks.

"All rocks of the igneous class are presumed to have solidified from a molten state, either upon reaching the earth's surface or at varying depths beneath it. The physical conditions, such as heat and pressure, under which the molten rock magma consolidated, as well as its chemical composition and the presence of included vapors, are the chief features influencing the structure. Thus, we find the deep-seated, plutonic rocks coarsely crystalline with mineral constituents well defined, as in case of granite rocks, indicating a single, prolonged period of development, whereas the members of the extrusive or volcanic types, solidifying more rapidly at the surface, are either fine-grained or frequently glassy and vesicular, or show a prophyritic structure. This structure is produced by the development of large crystals in a more or less dense and fine-grained ground mass, and is caused generally by a recurrence of mineral growth during the effusive period of magmatic consolidation.

"In the arrangement of the rock families from a mineralogical standpoint it will be noted that the plutonic rock types, granite, syenite, and diorite, are represented by their equivalent extrusive varieties, rhyolite and andesite, and that diabase has been included, somewhat arbitrarily, with basalt, as a volcanic representative of gabbro. These latter rocks are of special interest, owing to their wide distribution and general use in road construction. They occur in the forms of dykes, intruded sheets, or volcanic flows, and vary in structure from glassy-porphyritic (typical basalt) to wholly crystalline and even granular (diabase). Their desirable qualities for road-building are caused to a large extent by a peculiar interlocking of the mineral components (ophitic structure), yielding a very tough and resistant material well qualified to sustain the wear of traffic.

"Igneous rocks vary in color from the light gray, pink, and brown of the acid granites, syenites, and their volcanic equivalents (rhyolite, andesite, etc.) to the dark steel-gray or black of the basic gabbro, peridotite, diabase, and basalt. The darker varieties are commonly called trap. This term is in very general use and is derived from *trappa*, Swedish for stair, because rocks of this kind on cooling frequently break into large tabular mas es, as may be seen in the exposures of diabase on the west shore ot the Hudson River from Jersey City to Haverstraw.

Sedimentary Rocks.

"The sedimentary rocks as a class represent the consolidated products of former rock disintegration, as in the case of sandstone, conglomerate, shale, etc., or they have been formed from an accumulation of organic remains chiefly of a calcareous nature, as is true of limestone and dolomite. These fragmental or clastic materials have been transported by water and deposited mechanically in layers on the sea or lake bottoms, producing a very characteristic bedded or stratified structure in many of the resulting rocks.

"In the case of certain oolitic and travertine limestones, hydrated iron oxides, siliceous deposits, such as geyserite, opal, flint, chert, etc., the materials have been formed chiefly by chemical precipitation and show generally a concentric or colloidal structure.[1] Oolitic and pisolitic limestones consist of rounded pealike grains of calcic carbonate held together by a calcareous cement. Travertine is the so-called 'onyx marble' of Mexico and Arizona. It is a compact rock, concentric in structure and formed by the precipitation of carbonate of lime from the waters of springs and streams.

"Loose or unconsolidated rock débris of a prevailing siliceous nature comprise the sands, gravels, finer silts, and clays (laterite, adobe, loess, etc.). Shell sands and marls, on the other hand, are mainly calcareous, and are formed by an accumulation of the marine shells and of lime-secreting animals. Closely associated with the latter deposits in point of origin are the beds of diatomaceous or infusorial earth composed almost entirely of the siliceous casts of diatoms, a low order of seaweed or algæ.

"This unconsolidated material may pass by imperceptible gradations into representative rock types through simple processes of induration. Thus clay becomes shale, and that in turn slate, without necessarily changing the chemical or mineralogical composition of the original substance.

"Such terms as flagstone, freestone, brownstone, bluestone, graystone, etc., are generally given to sandstones of various colors and composition, while puddingstone, conglomerate, breccia, etc., apply to consolidated gravels and coarse feldspathic sands.

"The calcareous rocks are of many colors, according to the amount and character of the impurities present.

Metamorphic Rocks.

"Rocks of this class are such as have been produced by prolonged action of physical and chemical forces (heat, pressure, moisture, etc.) on both sedimentary and igneous rocks alike. The foliated types (gneiss, schist, etc.) represent an advanced stage of metamorphism on a large scale (regional metamorphism), and the peculiar schistose or foliated structure is due to the more or less parallel arrangement of their mineral components. The non-foliated types (quartzite, marble, slate, etc.) have resulted from the alteration of sedimentary rocks without materially affecting the structure and chemical composition of the original material.

"Rocks formed by contact metamorphism and hydration, such as hornfels, pyroxene marble, serpentine, serpentineous limestone, etc., are of great interest from a petrographical standpoint, but are rarely of importance as road materials.

"The color of metamorphic rocks varies between gray and white of the purer marbles and quartzites to dark gray and green of the gneisses, schists, and amphibolites. The green varieties are commonly known as greenstones, or greenstone schists."

[1] G. P. Merrill's " Rocks, Rock Weathering, and Soils," 1897, pp. 104-114.

Interpretation of Tests.

It has been found impractical to specify definite qualities of stone for use in macadam highways. Economy and practical engineering demand that all available sources be considered. Tests are made to determine the relative qualities of stone from these different sources and the results used as a guide for selection.

In the work of the New York State Highway Commission all tests are tabulated geographically, using a county as a unit. Table Nos. 22 and 23 are compiled from the records of this department. It will be noted that comparisons are made in different classifications only, as it is considered that conclusions should not be drawn from a comparison of tests procured from materials having different origins and composed of different minerals.

For the purpose of ready comparison, there has been introduced a figure known as the "weighted value." (See last column Tables 22 and 23.) This is computed by giving relative weights of three to the French coefficient, two to the hardness, one to the toughness values and adding the three together. These relative weights were determined from a consideration of the amount of material used in the different tests and the personal equation in running them.

By consulting these tables the available rocks of different classifications in various sections throughout New York State can be determined readily, and as new tests are completed they are compared with good average material from that section.

Conclusions.

Trap (diabase), granite, gneiss, quartzite, sandstone and limestone are the most common rocks and when found in a good state of preservation make good surfacing materials.

As generally found, trap is uniform in hardness and toughness, making an excellent material for use in top course.

Granite and gneiss, where they occur with hornblende replacing a large percentage of the quartz, make an excellent surfacing stone.

Quartzites when found in good state of preservation are hard and tough. They should not be confused with crystalline quartz which is hard but brittle.

Sandstones are extremely variable and only the better varieties should be used.

Limestones range from the fine grained dense products which are hard and tough to the coarse grained soft products which are not suitable for surfacing.

Screenings.

Screenings act as a filler and binder for waterbound macadam and as a partial filler for bituminous macadam. For use in waterbound construction the main mineral constituent is the most essential feature to be considered as this must be a material that will form a binder and "puddle" readily when subjected to the action of a road roller and water.

Limestone screenings have proved the most efficient as a binder in waterbound construction, although trap and some other igneous rocks can be bound with their own dust by repeated puddling. Screenings consisting mainly of quartz have never been used successfully in waterbound construction except by the addition of some limestone screenings. The use of a percentage of clay or loam as a binder is not advisable except where the cost of limestone screenings would be prohibitive.

Laboratory methods for testing the cementing power of rock powders are available but the results obtained are erratic and undependable.

In plain waterbound roads it is often necessary to mix some limestone screenings, fine sandy loam, or even a small percentage of clay loam with trap, granite, sandstone, quartzite, or gneiss screenings to get a good bond and prevent raveling in dry weather.

3. Bottom Course Macadam Stone

As the bottom stone simply spreads the wheel loads transmitted through the top course and is not directly subjected to the traffic action, almost any stone that breaks into cubical irregular shapes that will not air or water slake and that is hard enough to stand the action of the roller during construction will be satisfactory.

Any of the materials listed above in Table No. 24 except shale and slate can be used, provided that they are not rotten from long exposure in the air. The different available varieties are usually tested in the same manner as for top stone in order to pick the best.

4. Fillers

Fillers are used in the bottom course to fill the voids between the crushed stone and to prevent rocking or sidewise movement of the larger pieces.

They should be easy to manipulate in placing, should not soften when wet, or draw water up from the subgrade by capillary action.

The materials most used are

- Coarse sandy loam
- Coarse sand
- Gravel with large excess of fine material
- Stone screenings

The fitness of the material can be determined by inspection and by wetting a handful; if it gets sticky or works into a soft mud it should not be used.

5. Vitrified Brick

Bricks must withstand the same destructive agencies as described for top stone. They must be uniform in size, tough, hard, dense, evenly burned, and, on account of their peculiar shape, must have a high resistance against rupture. These properties are tested by the standard methods adopted by the American Brick Manufacturers' Association, as described in the New York State specifications on page 390.

It should be understood that bricks suitable for paving are manufactured in a different way and of different materials than ordinary building bricks.

"The materials for molding any paving brick must be of a peculiar character which will not melt and flow when exposed to an intense heat for a number of days but will gradually fuse and form vitreous combinations throughout while still retaining its form.

"The resulting brick must be a uniform block of dense texture in which the original stratification and granulation of the clay has been wholly lost by fusion which has stopped just short of melting the clay and forming glass.

"The clay while fusing must shrink equally throughout, thus causing the brick to be without laminations or of any exterior vitrified crust differing from the interior."[1]

The great majority of paving brick are made in Ohio, Illinois, Indiana, Pennsylvania, West Virginia, and New York. They are classed as shale or fire-clay brick.

6. Bituminous Binders

The subject of bitumens is an intricate one and the reader is referred to the works of Clifford Richardson, Prevost Hubbard, and others, for detailed information, as a book of this character can give only an outline.

There are a number of dust preventives and road binders on the market which depend for their effectiveness on a bituminous binding base. The term bitumen is applied to a great many substances. Hubbard arbitrarily defines bitumens as "consisting of a mixture of native or pyrogenetic hydrocarbons and their derivatives, which may be gaseous, liquid, a viscous liquid, or solid, but if solid melting more or less readily upon the application of heat, and soluble in chloroform, carbon bisulphide, and similar solvents."[2]

The bitumens may be classified as native and artificial. The native bituminous materials, that are used in road work, are the asphaltic and semi-asphaltic oils (dust layers), Malthas (the binding base of Rock Asphalts), Trinidad, Bermudez California, and Cuba asphalts, Gilsonite, and Grahamite (which, however, are too brittle in their natural state and require fluxing with a suitable residual oil before they can be used as binders). The natural asphalts are refined to remove water and any objectionable amount of impurities by heating until the gases are driven off, skimming the vegetable matter which rises to the surface, and removing the mineral constituents which fall to the bottom.

The artificial bituminous materials are derived by the destructive distillation of coal, or by fractional distillation of crude coal tars, or the native petroleum oils. They comprise the crude coal and water gas tars, the refined tars, the residual oils and semi-solid binders derived from the petroleum oils. They vary greatly in consistency and binding power.

[1] Judson's "Roads and Pavements," page 87.

[2] "Dust Preventives and Road Binders." John Wiley & Sons.

The following material is briefed from Bulletin No. 34, United States Office of Public Roads: The light oils and tars have a relative small percentage of bituminous base and are effective only so long as it retains its binding power; the more permanent binders contain a larger percentage of bitumen; these are the heavy oils and semi-solids.

Artificial Bitumens.

Crude Tars. — Coke ovens and gas plants produce most of the coal tars in use. These tars contain various complex combinations of carbon, hydrogen, and oxygen and small amounts of nitrogen and sulphur. They vary in composition according to the material from which they are made and the temperature at which they are distilled. The percentage of free carbon ranges from 5 per cent to 35 per cent, and the bitumen from 60 per cent to 95 per cent, depending on the temperature of manufacture. Tars produced at high temperatures contain free carbon in excess which weakens their binding power; they, also, contain a large amount of anthracine and naphthalene, two useless materials from the standpoint of road work. Tars produced at low temperatures are to be preferred. Coke tar is low temperature tar; gas tar is high temperature tar.

Refined Tars. — Much of the road tar is refined tar — that is, it has been subjected to fractional distillation to remove the valuable volatile compounds. The residuum from this process is a thick viscous material known as coal-tar pitch, and if the crude tar from which it is obtained was produced at a low temperature it is nearly pure bitumen; the dead oils obtained from the distillation are of little value and are often run back into the pitch, which makes it liquid when cold. The following table gives the approximate composition of water-gas tar, crude coal-tar, and refined tar.

TABLE 25. SPECIFIC GRAVITY AND COMPOSITION OF TAR PRODUCTS

Table from Bulletin No. 34 United States Office of Public Roads

Kind of Tar	Specific Gravity	Ammoniacal Water	Total Light Oils to 170° C.	Total Dead Oils 170° 270° C.	Residue (by Difference)
		%	%	%	%
Water-gas tar . . .	1.041	2.4	*a*21.6	*b*52.0	*c*24.0
Crude coal tar . .	1.210	2.0	*d*17.2	*e*26.0	*f*54.8
Refined coal tar .	1.177	0.0	*b*12.8	*g*47.6	*f*39.6

a Distillate mostly liquid.
b Distillate all liquid.
c Pitch very brittle.
d Distillate mostly solid.
e Distillate one-half solid.
f Pitch hard and brittle.
g Distillate one-third solid.

Table 25 A gives a more up-to-date analysis of the coal tars on the market.

The tests and detailed requirements for light, medium, and heavy bitumens are given in specifications, page 377.

If the tar is used as a temporary dust-layer only, it should be a low-temperature, dehydrated tar, liquid when cold. If used as a

TABLE 25 A. CIRCULAR NO. 97, U. S. OFFICE OF PUBLIC ROADS

Analysis of crude coke-oven tars produced in the United States and Canada.

Serial No.	General Information		Maximum temperature of firing retorts
	Company and location	Type of Oven	
5126	Solvay Process Co., Syracuse, N.Y.	Semet-Solvay	1650–1450° C.
5123	Semet-Solvay Co., Pennsylvania Steel Co., Steelton, Pa.	"	1050–1450° C.
5124	Semet-Solvay Co. National Tube Co., Benwood, W.Va.	"	1050–1450° C.
5137	Semet-Solvay Co., Milwaukee Coke & Gas Co., Milwaukee, Wis.	"	1050–1450° C.
5121	Semet-Solvay Co. Pennsylvania Steel Co., Lebanon, Pa.	"	1050–1450° C.
5125	By-Products Coke Corporation, South Chicago, Ill	"	1050–1450° C.
5128	Semet-Solvay Co., Detroit, Mich.	"	1050–1450° C.
5200	Semet-Solvay Co., Empire Coke Co., Geneva, N.Y.	"	1050–1450° C.
5189	Semet-Solvay Co., Dunbar Furnace Co., Dunbar, Pa.	"	1050–1450° C.
5160	Semet-Solvay Co., Central Iron & Coal Co., Tuscaloosa, Ala.	"	1250° C.
5074	Philadelphia Suburban Gas & Electric Co., Chester, Pa.	"	1050° C.
5081	Semet-Solvay Co., Ensley, Ala.	"	1250° C.
5095	The N. E. Gas & Coke Co., Everett, Mass.	Otto Hoffman	[1] 1100° C.
5083	Lackawanna Steel Co., Lackawanna Iron & Steel Co., Lebanon, Pa.	"	1000° C. (1800° F.)
5159	Dominion Tar & Chemical Co., Sydney, Nova Scotia	"	(2)
5107	Hamilton Otto Coke Co., Hamilton, Ohio.	"	1111° C. (2000° F.)
5086	Carnegie Steel Co., South Sharon, Pa.	United Otto	1666° C. (3000° F.)
5078	Maryland Steel Co., Sparrows Point, Md.	"	1333° C. (2400 F.)
5087	Citizens' Gas Co., Indianapolis, Ind.	"	1222° C. (2200 F.)
5109	Pittsburg Gas & Coke Co., The United Coke & Gas Co., Glassport, Pa.	"	(2)
5122	Zenith Furnace Co., Duluth, Minn.	"	1222-1277°C. 2200-2300°F.
5188	Illinois Steel Co., Joliet, Ill.	Koppers	1444° C. (2600° F.)
5404	Illinois Steel Co., Indiana Steel Co., Gary, Ind.	"	1100° C.
5108	Camden Coke Co., Camden, N.J.	Otto Hoffman United Otto	1000° C. (1800° F.) 1222° C. (2200° F.)
5127	Cambria Steel Co., Johnstown, Pa.	Otto Hoffman United Otto	1111° C. (2000° F.) 1111° C. (2000° F.)
5089	Lackawanna Steel Co., Buffalo, N.Y.	United Otto Rothberg	1000° C. (1800° F.) 1000° C. (1800° F.)

TABLE 25 A — *Continued*

Answers to Questions			Examination			
Maximum temperature to which coal is brought	Specific gravity of crude tar	Per cent of free carbon in tar	Specific gravity of tar, 25° C.	Per cent of free carbon	Per cent of ash	Per cent soluble in CS_2, including H_2O
950–1150° C.	1.12–1.21	3–12	1.195	7.76	0.12	92.12
950–1150° C.	1.12–1.21	3–12	1.206	8.77	.07	91.16
950–1150° C.	1.12–1.21	3–12	1.176	7.14	.04	92.82
950–1150° C.	1.12–1.21	3–12	1.168	6.10	.05	93.85
950–1150° C.	1.12–1.21	3–12	1.173	4.71	.06	95.23
950–1150° C.	1.12–1.21	3–12	1.191	7.49	.03	92.48
950–1150° C.	1.12–1.21	3–12	1.169	6.56	.11	93.33
950–1150° C.	1.12–1.21	3–12	1.159	6.07	.08	93.85
950–1150° C.	1.12–1.21	3–12	1.181	8.85	.02	91.13
1150° C.	1.17	5.72	1.159	5.05	.02	94.93
1000° C.	1.16 (20° C.)	—	1.141	3.96	.05	95.99
1150° C.	1.17 (15° C.)	8	1.175	6.90	.06	93.04
[1] 1200° C.	1.17	8–10	1.160	13.94	.00	86.06
1000° C. (1800° F.)	1.10	16–24	1.214	14.05	.13	85.82
[2]	1.170	10–15	1.143	10.81	.05	89.14
1111° C. (2000° F.)	1.14	[6] 16.0	1.160	8.37	.06	91.57
1444° C. (2600° F.)	1.2	7.09–10.64	1.191	7.89	.03	92.08
1222° C. (2200° F.)	[3] 1.19	[3] 8–10	1.179	8.49	.03	91.48
1222° C. (2200° F.)	1.14–1.15	4–5	1.133	5.21	.07	94.72
[2]	(50° F.) 1.207 10° C.	16.59	1.176	10.53	.04	89.43
[2]	[2]	[2]	1.195	12.18	.05	87.77
1388° C (2500° F.)	1.16–1.20	12–15	1.171	3.89	.06	96.05
880–950° C.	[4] 1.174 1.169	4.35	1.169	2.73	.04	97.23
833° C. (1500° F.) 1055° C. (1900°F.)	1.20–1.30 [5] (1.221)	7–9 [5] (7.3)	1.182	11.30	.06	88.64
[1] 1111° C. (2000° F.) [1] 1111° C. (2000° F.)	1.12	[1] 15	1.211	12.40	.16	87.44
1000° C. (1800° F.) 1000° C. (1800° F.)	1.16	16–24	1.210	16.80	.00	83.20

TABLE 25 A — *Continued*

Serial No.	Company and Location	Examination, Public Roads — Distillation results — Water, % by vol.	Water, % by weight	Light oils up to 110° C., % by vol.	Light oils up to 110° C., % by weight
5126	Solvay Process Co., Syracuse, N.Y.	1.0	0.8	[8] 0.3	0.3
5123	Semet-Solvay Co., Pennsylvania Steel Co., Steelton, Pa.	1.0	.8	.4	.3
5124	Semet-Solvay Co., National Tube Co., Benwood, W.Va.	1.1	1.0	1.9	1.5
5137	Semet-Solvay Co., Milwaukee Coke & Gas Co., Milwaukee, Wis.	1.8	1.5	1.4	1.2
5121	Semet-Solvay Co., Pennsylvania Steel Co., Lebanon, Pa.	.6	.5	1.6	1.3
5125	By-Products Coke Corporation, South Chicago, Ill.	(7)	(7)	.4	.3
5128	Semet-Solvay Co., Detroit, Mich.	6.9	5.9	[9] 2.8	2.3
5200	Semet-Solvay Co., Empire Coke Co., Geneva, N.Y.	4.0	3.4	2.6	2.1
5189	Semet-Solvay Co., Dunbar Furnace Co., Dunbar, Pa.	2.0	1.7	1.7	1.4
5160	Semet-Solvay Co., Central Iron & Coal Co., Tuscaloosa, Ala.	3.2	2.8	2.4	1.9
5074	Philadelphia Suburban Gas & Electric Co., Chester, Pa.	2.3	2.0	2.3	1.3
5081	Semet-Solvay Co., Ensley, Ala.	3.3	2.8	[8] 1.4	1.0
5095	The New England Gas & Coke Co., Everett, Mass.	2.2	2.0	2.9	2.3
5083	Lackawanna Steel Co., Lackawanna Iron & Steel Co., Lebanon, Pa.	5.4	4.4	[9] 1.4	1.4
5159	Dominion Tar & Chemical Co., Sydney, Nova Scotia	3.2	2.8	1.9	1.5
5107	Hamilton Otto Coke Co., Hamilton, O.	3.4	3.0	3.1	2.5
5086	Carnegie Steel Co., South Sharon, Pa.	1.0	1.0	[9] 1.6	1.2
5078	Maryland Steel Co., Sparrows Point, Md.				
5087	Citizens' Gas Co., Indianapolis, Ind.	1.6	1.3	1.3	.9
5109	Pittsburg Gas & Coke Co., The United Coke & Gas Co., Glassport, Pa.	1.2	1.1	1.1	.9
5122	Zenith Furnace Co., Duluth, Minn.	1.1	1.0	1.1	.9
5188	Illinois Steel Co., Joliet, Ill.	3.6	3.0	1.7	1.3
5404	Illinois Steel Co., Indiana Steel Co.,	1.9	1.6	[9] 1.7	1.2
	Gary, Ind.	3.5	3.0	[9] 1.3	1.0
5108	Camden Coke Co., Camden, N.J.	2.2	1.9	1.8	1.4
5127	Cambria Steel Co., Johnstown, Pa.	10.1	8.3	[9] 3.1	2.3
5089	Lackawanna Steel Co., Buffalo, N.Y.	2.7	2.2	[10] .5	.3

REFERENCES TO TABLE 25 A

1 Approximately.
2 No information.
3 Varies with coal. Coal with 28 per cent of volatile matter used.
4 With H_2O.
5 At present.
6 Variable.
7 Trace.
8 Trace of solids.
9 Distillate, solid.
10 Distillate, one-fourth solid.
11 Distillate, nine-tenths solid.
12 Distillate, three-fourths solid.
13 Distillate, eight-ninths solid.
14 Distillate, one-half solid.

TABLE 25 A — *Continued*

Examination, Office of Public Roads								
Distillation results								
Middle oils, 110°–170 C.		Heavy oils, 170°–270 C.		Heavy oils, 270°–315° C.		Pitch		Serial No.
% by vol.	% by weight	% by vol.	% by weight	% by vol.	% by weight	% by vol.	% by weight	
0.8	0.7	[12] 13.1	11.5	[19] 8.2	7.3	[25] 76.6	79.1	5126
[9] 2.0	1.7	[9] 14.0	12.3	[20] 7.9	6.9	[26] 74.7	77.6	5123
.7	.6	14.9	13.2	[21] 11.9	10.6	[27] 69.5	73.1	5124
.8	.6	[13] 21.1	18.9	[20] 5.5	4.9	[25] 69.4	72.5	5137
.8	.6	[14] 17.5	15.5	[19] 9.4	8.4	[25] 70.1	73.7	5121
[12] 1.1	.9	[15] 23.6	20.7	[9] 9.8	8.9	[27] 65.1	68.9	5125
.4	.3	[11] 14.6	13.0	[8] 6.9	5.7	[26] 68.4	72.0	5128
.6	.5	[10] 17.6	15.5	[22] 11.4	10.4	[27] 63.8	67.7	5200
.2	.2	[16] 20.0	17.8	[21] 6.5	5.7	[25] 69.6	73.1	5189
.3	.3	18.6	16.3	[10] 7.5	6.8	[27] 68.0	71.5	5160
1.2	.8	22.8	19.5	[10] 13.6	12.5	57.8	62.0	5074
.2	.2	[17] 16.5	14.1	[14] 9.3	8.2	[27] 69.3	73.2	5081
.6	.5	23.5	20.4	[17] 15.6	14.4	[27] 55.2	59.7	5095
[9] .1	.1	[11] 13.0	10.9	[21] 9.4	8.1	[25] 70.7	74.6	5083
.6	.5	27.2	24.2	[19] 7.3	6.7	[27] 59.8	63.5	5159
.7	.6	27.9	24.4	[19] 3.8	3.5	[27] 61.1	64.9	5107
[9] .6	.4	[16] 12.1	10.2	[19] 11.0	9.7	[25] 73.7	77.5	5086
.6	.4	[12] 17.2	15.1	[21] 9.6	8.5	[28] 69.7	73.2	5078
1.4	1.3	23.9	21.4	[10] 11.6	10.4	[27] 60.8	64.7	5087
.5	.4	[18] 26.9	23.6	[14] 6.9	6.3	[27] 63.5	67.6	5109
.4	.3	[11] 18.1	15.9	[19] 12.5	11.1	[27] 63.7	67.8	5122
[9] .2	.2	[9] 20.0	18.0	[11] 13.4	12.0	[26] 62.8	66.3	5188
[9] .4	.3	[9] 20.6	18.5	[9] 7.1	6.5	[26] 67.1	70.2	5404
.6	.5	[14] 20.5	18.2	[23] 8.5	7.5	[25] 66.4	70.1	5108
[8] .3	.2	[9] 7.1	6.1	[12] 7.4	6.9	[26] 72.0	74.8	5127
[9] 2.2	1.7	[9] 11.7	9.9	[24] 11.8	10.2	[27] 71.1	75.0	5089

REFERENCES TO TABLE 25 A

[15] Distillate, two-thirds solid.
[16] Distillate, four-fifths solid.
[17] Distillate, seven-eighths solid.
[18] Distillate, one-ninth solid.
[19] Distillate, one-third solid.
[20] Distillate, one-sixth solid.
[21] Distillate, one-fifth solid.
[22] Distillate, two-fifths solid.
[23] Distillate, one-seventh solid.
[24] Distillate, three-fifths solid.
[25] Pitch, soft and sticky.
[26] Pitch, very soft and sticky.
[27] Pitch, hard and brittle.
[28] Pitch, plastic.

more permanent binder and applied hot, it should have a larger percentage of pitch, should contain no water, and be free from an excessive amount of free carbon. If used as a mastic in bituminous macadam, it should contain a high percentage of pitch and be free from the defects mentioned.

Natural Bitumens and Artificial Residual Oils and Semi-Solids.

Mineral oils can be classed as paraffin petroleums, mixed paraffin and asphaltic petroleums, and asphaltic petroleums. The relative value of oils as a source of supply for road materials depends on their percentage of asphaltic residue. The eastern oils found in New York, Pennsylvania, West Virginia, etc., are paraffin petroleums; the western oils vary from light to heavy asphaltic petroleums, and the southern oils have a mixed paraffin and asphaltic base.

The crude petroleum is refined by fractional distillation to obtain its valuable products, such as kerosene, etc. The character of the residue depends, as for the tars, on the crude material and the method of manufacture; the operation known as "cracking," which is used to increase the yield of the inflammable oils, produces an excess of free carbon.

The paraffin petroleum residuums are soft and greasy and are not suitable for road work; they contain a large amount of the paraffin hydrocarbons and paraffin scale (crude paraffin).

The California petroleum residuums resemble asphalt, and if carefully distilled without cracking should contain little or no free carbon. They are suited to road work.

The Texas, or semi-asphaltic petroleums contain some paraffin hydrocarbons and about 1 per cent of paraffin scale. Residuums from these oils, if containing a relatively small amount of paraffin, can be successfully used.

The tests and required properties of residuum bituminous binders used on the New York State roads in 1914 are given in specifications, page 377.

The following tables give a general idea of the relative characteristics of the crude petroleums and petroleum residuums.

TABLE NO. 26. RESULTS OF TESTS OF CRUDE PETROLEUM

Tables from Bulletin No. 34 United States Office of Public Roads

Kinds of Oil	Specific Gravity	Flash Point °C.	Volatility at 110° C. 7 Hours	Volatility at 160° C. 7 Hours	Volatility at 205° C. 7 Hours	Residue
			%	%	%	%
Pennsylvania, paraffin....	0.801	(*a*)	47.3	58.0	68.0	*b*32.0
Texas, semi-asphaltic	.904	43	20.0	27.0	49.0	*c*51.0
California, asphaltic	.939	26	....	....	*d*42.7	*e*57.3

a Ordinary temperature
b Soft
c Quick flow
d Volatility at 200°, 7 hours.
e Soft maltha; sticky

RESULTS OF PETROLEUM RESIDUUM

Kinds of Oil	Specific Gravity	Flash Point ° C.	Volatility at 200° C. 7 Hours	Residue	Solid Paraffin	Fixed Carbon
			%	%	%	%
Pennsylvania, paraffin....	0.920	186	14.2	a85.8	11.0	3.0
Texas, semi-asphaltic	.974	214	6.2	a93.8	1.7	3.5
California, asphaltic	1.006	191	17.3	a82.7	0.0	6.0

a Soft.

Tests of Bitumens and their Significance.

Bitumens for use as the cementing material in road construction may, according to their source and characteristics, be divided into the two general classes of asphalts and tars.

The asphalts suitable for use as the cementing agent in road construction are produced either by reducing asphaltic base petroleum to a suitable consistency by the distillation process or by softening the so-called solid asphalts to a suitable consistency by the addition of flux produced by the partial distillation of petroleum.

The different grades, relative to consistency, of road oils are usually produced by the partial reduction of asphaltic base petroleum.

By the destructive distillation of bituminous coals or the "cracking" of petroleum oils during the carburetting process in the manufacture of water gas, crude tars are produced. These crude tars are refined or reduced by distillation to a suitable consistency for use in road construction.

Bitumens are used in road construction for the purpose of waterproofing the surface and adding to the mechanical bond of the mineral aggregate by cementing together the finer particles of mineral matter, thus preventing their displacement under the action of traffic and retaining them in the road surface where they fill the interstices between the larger stone and bind them together.

The desirable characteristics of bituminous material for road building purposes are, first, *Adhesiveness*, second, *Non-Susceptibility* to changes in temperature, and third, *Stability* or "life." The chief object of bituminous material specifications is to make imperative these desirable qualities of the material.

In connection with testing bituminous materials the thought should be kept in mind that the laboratory results obtained in the different tests are largely for comparative purposes. By this means new or but little used materials may be compared with materials which have proven satisfactory under service tests. Also laboratory results furnish an accurate means to specify the exact characteristics of the material desired for any given purpose.

Adhesiveness.

The adhesiveness of the material is provided for in specifications by suitable requirements of ductility and toughness.

The ductility and toughness tests are made for the purpose of determining the adhesive and binding qualities of the material under different conditions of temperature. The ductility test is made by determining the distance a briquette of the material, having a standard cross-section (1 sq. cm.) will draw out before breaking. Since temperature effects the results, a standard temperature of 77 degrees Fahrenheit, has been adopted generally for making this test. Experience teaches that the greater the distance that a briquette of the material will stretch out before breaking the more sticky and adhesive the material. This test may be performed in a rough manner by pulling out a small roll of the material between the fingers. Material which will not pull out to a long thread before breaking is usually spoken of as "short." Such materials are not adhesive or sticky and it is extremely difficult to bind a road with them, even under the most favorable circumstances.

As stated, the ductility test is usually made at a temperature of 77 degrees Fahrenheit and thus measures the adhesiveness of the material at a rather high temperature. To obtain an indication of the character of the material at a low temperature the Toughness test is made at a temperature of 32 degrees Fahrenheit. This test is performed by dropping a weight of 2 kilograms on a cylinder of the material $1\frac{3}{4}$ inches in diameter by $1\frac{3}{4}$ inches in height. The first height of the drop is usually from a distance of 5 cm. and is gradually increased until rupture of the cylinder occurs. A rough field test for toughness may be performed by noting whether a piece of the material will fracture under a sharp blow. If the temperature of the material is about 32 degrees Fahrenheit, the results will be more indicative of the character of the material.

Bitumens which are brittle or which give a low toughness result, lose their binding value in cold weather and roads constructed by their use are apt to ravel and break up under traffic.

Bitumens which give good ductility and toughness results under the methods outlined, will give satisfactory results as the cementing medium when used in road construction provided the other construction details have been properly followed out.

In connection with the stickiness and adhesiveness of bitumens the fact should always be kept in mind that their purpose in road construction as cementing medium, is most effective when used with a hard, clean, dry mineral aggregate. As the departure from these qualities of the mineral aggregate is increased so also are increased the difficulties of getting a satisfactory road surface firmly bound together.

Susceptibility to Changes in Temperature.

The susceptibility to changes in temperature is shown by the relative hardness as indicated by the penetration tests at different temperatures, as 32 degrees Fahrenheit, 77 degrees Fahrenheit and 115 degrees Fahrenheit.

The consistency of asphalts is referred to as the "penetration." The penetration test is made by measuring the distance in hundredths of a centimeter that a standard needle under a stated load, applied

for a stated time, will penetrate into it vertically. These variable factors are usually as follows:

Needle — R. J. Roberts' Parabola "Sharps" No. 2.
at 32° F. 200 gram weight, 1 minute,
at 77° F. 100 gram weight, 5 seconds,
at 115° F. 50 gram weight, 5 seconds.

The material which is the most susceptible to changes in temperature will show the greatest variation in penetration under varying conditions of temperature. Roads constructed by the use of materials which are extremely susceptible to changes in temperature become soft in warm weather, mark easily, have a tendency to rut and become wavy. In cold weather this material becomes very hard and slippery and is apt to be brittle and become chipped from the road surface.

In addition to the general qualities of bitumens which are shown by penetration tests, this test is used in specifications to define within narrow limits the consistency of the material. The consistency limits placed in specifications are governed by the climate and the type of construction to be followed, also the general size of the mineral aggregate to be used. When the penetration method of construction is followed it is necessary to use a relatively soft asphalt in order that it may be incorporated in the road surface. In the mixing types of construction a harder asphalt may be incorporated with the mineral aggregate. The use of a hard asphalt together with a graded mineral aggregate gives a dense wearing surface that does not readily become wavy under traffic.

The information obtained by the penetration test is not readily checked in the field without the aid of laboratory apparatus, but as a general rule bitumens which are suitable for binders are plastic when "worked" in the hands.

Stability.

When the term "Stability" or "Life" is used in reference to bitumens it refers to the quality of the material by which it retains its characteristics, usually as defined by the specifications, over a long period of time. The laboratory tests which indicate this property are the evaporation test, the ratio of the penetration after evaporation to the original penetration, and the flash point.

The heating or evaporation test, is made by placing 50 grams of the material in a flat bottomed dish $2\frac{3}{16}$ inches in diameter by $1\frac{3}{8}$ inches in depth. This is placed in an oven maintained at a specified temperature, usually 325 degrees Fahrenheit for a period of 5 hours.

This test may be considered as an accelerated test on the material. In a binder, the percentage lost by weight together with the resulting hardening as shown by the relative penetration, i. e., the ratio of the original penetration to the penetration after evaporation, are indicative of the "life" of the material. The less the evaporation loss and the less the hardening as shown by the relative penetration the greater will be the "life" of the material.

In an oil used for surface application the evaporation test shows the presence and quantity of light oils. This is indicative of the time required for the oil to "set up" after application to the road surface; the evaporation from the large surface area of the oil as applied to the road being roughly comparable with evaporation from the smallest surface area of the oil exposed at the higher temperature at which the test is made.

The open flash test is made by heating at the rate of about 10 degrees Fahrenheit per minute, a small quantity of the material, approximately 40 grams in a dish of approximately the same size as the dish used for the penetration tests, $2\frac{3}{16}$ inches in diameter by $1\frac{3}{8}$ inches in depth. A small flame from a capillary tube is passed over the surface of the oil at each increase of 5 degrees in temperature.

A slight "puff" or explosion indicates the flash point has been reached. The presence of light oils or distillates is indicated by a low flash point. The flash point together with the evaporation results give an indication as to the methods and materials used in the manufacture of the bitumen which is being tested.

Unless "cut-back" materials are being tested, in which an exceedingly light distillate as naphtha or benzole has been used as the "cut-back" agent, considerable "smoke" will be given off from the sample before the flash point is reached. This feature should be kept in mind when material is being heated for application in the field. Material should never be heated in the field to a point when it smokes profusely, for at such a temperature the material is being "burned" or hardened to such an extent that it loses its adhesiveness and becomes brittle when cold, thus failing to become a binding or cementing agent which binds the mineral aggregate of the road together.

The same "burning" effect on the material is produced by keeping it at a temperature below the "smoking point" for a long period, (several hours) as would be produced at a higher temperature for a shorter period of time. This important feature should always be kept in mind when heating material for application in the field.

Such tests as those for water, specific gravity, purity, paraffine, etc. are usually placed in specifications in addition to the tests which govern adhesiveness, non-susceptibility and stability for the purpose of identification of materials used, methods of manufacture, degree of refinement and care used in refining.

The presence of water in bituminous materials causes frothing when heated to a temperature of about 212 degrees Fahrenheit. In addition to the difficulty experienced in heating material containing water, due to the frothing, an even application or distribution to the road of such material is extremely difficult, due to the presence of the froth which is apt to be applied rather than the liquid bitumen.

Tests for specific gravity, purity, paraffine, etc. require laboratory apparatus to get results which indicate qualities of the material. The information obtained by these tests cannot be obtained by field tests.

If we assume that a suitable bitumen has been specified and obtained for construction work in which a bitumen is to serve as the cementing material, the results obtained, relative to the bitumen, will depend upon:

1. Not over-heating (by high temperature or long time) the bitumen.

2. The use of hard, clean, dry stone.

Grading of the mineral aggregate to reduce the voids and obtain greater density.

4. Thorough and uniform incorporation of the bitumen with the mineral aggregate.

5. Maximum consolidation, by rolling when laid.

When bituminous materials which may be applied cold are to be applied to a road surface, that surface should first be put in good condition. Surface application treatment is for the purpose of preserving a road which is in good condition and not repairing an uneven road. We do not repair a house by painting it; rather we repair the house and then paint it, in order that it may remain in good condition. An attempt to build up a road wearing surface by the use of bitumens which may be applied cold usually results in a surface which is easily marked, ruts and pushes into waves.

Cement.

There are five different classes of cement, Portland, Natural, Pozzolan, Iron Ore, and Magnesia cements. Of these the Portland or Natural is usually specified.

Portland cement is the term applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent has been made subsequent to calcination. (Amer. Soc. Testing Materials 1915 — page 353.)

Natural cement is the term applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas. (Amer. Soc. Testing Materials 1915 — p. 352.)

Portland cements are usually heavier, stronger, slower testing, and more uniform than the natural cements and are generally used for road structures, such as culverts, retaining walls, etc.; Portland cement is practically the only cement used to any extent in the United States at the present time. The few manufacturers of natural cement who were retaining a hold on the market some few years back when the production of Portland cement was expensive, are finding it difficult to compete with this latter product at its present price and quality.

The following is the standard specification for Portland cement as adopted by the American Society of Civil Engineers and the American Society for Testing Materials:

First: Specific gravity. The specific gravity of cement shall not be less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon a sample ignited at a low red heat. The loss in weight of the ignited cement shall not exceed 4 per cent.

Second: Fineness. It shall leave by weight a residue of not more than 8 per cent on the number 100, and not more than 25 per cent on the number 200 sieve.

Third: Time of Setting. It shall not develop initial set in less than thirty minutes; and must develop hard set in not less than one hour, nor more than ten hours.

Fourth: Tensile Strength. The minimum requirements for tensile strength for briquettes one square inch in cross section shall be as follows and the cement shall show no retrogression in strength within the periods specified:

Age	Neat Cement	Strength
24 hours in moist air		175 lbs.
7 days (1 day in moist air, 6 days in water)		500 "
28 " (1 " " " , 27 " " ")		600 "

One Part Cement — Three Parts Standard Ottawa Sand

7 days (1 day in moist air, 6 days in water)	200 lbs.
28 " (1 " " " , 27 " " ")	275 "

Fifth: Constancy of Volume. Pats of neat cement about three inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*) Another pat is kept in water maintained as near 70 degrees F. as practicable, and observed at intervals for at least 28 days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

These pats, to satisfactorily pass the requirements, shall remain firm and hard, and show no signs of distortion, checking, cracking or disintegrating.

Sixth: Chemical Composition. The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3), nor more than 4 per cent of magnesia (MgO).

The methods used in testing cement are standardized in detail and can be obtained in the "Year Book" of 1913, published by the American Society for Testing Materials or Committee report on "Uniform Tests of Cement" of the American Society of Civil Engineers 1912.

Concrete Materials

Fine Aggregate.

Fine aggregate for use in concrete should consist of sand free from any deleterious matter. Any sand which shows a coating on the grains should not be used until satisfactorily cleansed by washing.

The following tests are made on sand to determine its suitability for use in different classes of concrete:

1st. Gradation.
2nd. Percentage of voids.
3rd. Percentage of loam or silt.
4th. Compressive or tensile strength in cement mortar.

In order to secure suitable qualities, minimum requirements determined from the above tests should be definitely specified.

The following specifications are now being used by Highway Departments in several of the States:

Sand for use in Portland cement concrete roads shall be of the following gradation: 100 per cent shall pass a $\frac{1}{4}''$ screen, not more than 20 per cent shall pass a No. 50 sieve and not more than 6 per cent shall pass a No. 100 sieve. Sand may be rejected for this class if it contains more than 5 per cent of loam and silt. Mortar in the proportion of one part of cement to three parts of the sand, shall develop a compressive or tensile strength at least equal to the strength of a similar mortar of the same are, composed of the same cement and standard Ottawa sand.

Sand for use in foundations, culverts, retaining walls, etc. shall not contain more than 8 per cent of loam and silt. Mortar in the proportion of one part of cement to three parts of the sand, when tested shall develop a compressive or tensile strength of at least 80 per cent of the strength of a similar mortar of the same age, composed of the same cement and standard Ottawa sand.

Screenings if substituted wholly or in part for the above sand, should meet the following requirements:

They shall be free from dust coating or other dirt. 100 per cent shall pass a $\frac{1}{4}''$ screen and not more than 6 per cent shall pass a No. 100 sieve. Mortar in the proportions of three parts of the screenings or mixed screenings and sand, with one part of cement shall develop a strength equal to a sand for which it is to be substituted.

The best and safest way in the selection of a concrete sand is to have a fair representative sample from the deposit listed. After this is found to meet the requirements, it is necessary to have constant and careful field inspections and tests made as the deposit is worked.

The use of screenings is not advisable on any concrete work, except where a good grade of sand is not available. When used the product must be constantly inspected and tested as it is likely to vary to a considerable degree. Screenings from the softer limestones should not be used as the fine material is apt to "ball" in the mixer.

Sand used for grout in brick and stone block pavement must be fine enough to ensure it getting between the joints of the block, but an excessively fine sand should be avoided as it weakens the grout. Some states and many municipalities require the grout sand to pass a No. 20 sieve and not more than 30 per cent pass a No. 100 sieve. Such sand should not contain more than 5 per cent of loam and silt.

Coarse Aggregate.

Coarse aggregate for use in concrete should be of hard durable stone or gravel, free from coating of any kind. For use in concrete pavement, stone and gravel should be hard, tough and absolutely clean. For use in culverts, retaining walls, etc. stone and gravel should be of sound, unweathered material, clean and free from coating. It should not contain more than 10 per cent of soft stone or shale. Gravel containing a large percentage of thin flat stone should not be used.

For reinforced concrete the size of the stone is usually $\frac{1}{2}''$ to $1''$ in order to facilitate the compacting of the concrete between the reinforcing bars or mesh. For plain concrete a mixed size is used ranging from $\frac{1}{2}''$ to $3\frac{1}{2}''$; a scientifically graded stone reduces the amount of mortar required, but the structures in road work are so small that it does not pay to attempt to reduce the voids in this manner and the size that is available is used, varying the proportions of mortar to get a dense product.

PART II

THE PRACTICE OF THE SURVEY, DESIGN, ESTIMATES, AND CONSTRUCTION

CHAPTER VIII

THE SURVEY

As the survey furnishes the information for the design, it must be carefully made in regard to the essential features. These are alignment, levels and cross-sections, drainage, information concerning foundation soils, available stone supply, available sand, gravel, filler, etc.; direction and amount of traffic, railroad unloading points, the location of possible new sidings, and such topography along the road as will have a bearing on the design. The survey should be made not more than a year before construction starts and during the open season, as a snowfall of any depth makes the work unreliable and only fit for a rough estimate. When contracts based on winter surveys are awarded it is always necessary to take new cross sections to insure a fair estimate of the excavation.

A party of five men is a well-balanced force for surveys of this character.

Force	*Equipment*	*Stationery*
Engineer	Transit	Reports
Instrument man	Level	Pencils
Three helpers	2 100′ steel tapes	Notebook
	3 50′ metallic tapes	U.S. G. S. map.
	3 pickets	
	2 level rods	*Stakes*
	Pocket compass	For preliminary survey
	Hatchet	110 stakes per mile
	Sledge	For construction
	Axe	220 stakes per mile
	Keel	

The Center Line. The placing of the center-line hubs (transit points) requires good judgment and should be done by the chief of the party. In locating them he considers the principles of alignment discussed on page 17. The hubs are placed at tangent intersections and sometimes at the P. C.'s and P. T.'s of curves and are referenced to at least three permanent points

that will not be disturbed during construction. (See sample page of notes, Fig. 43.)

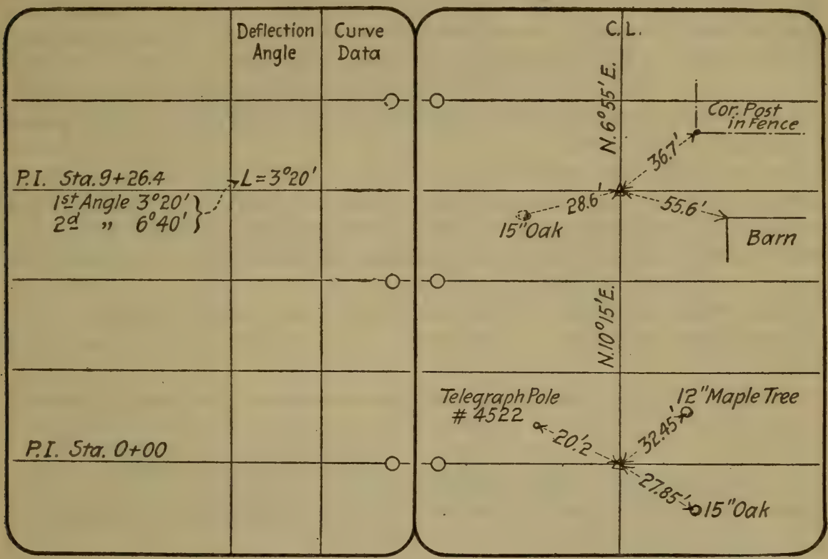


FIG. 43. — Alignment Notes

The deflection angles at the tangent intersections are usually read to the nearest minute, taking a double angle to avoid mistakes; the magnetic bearing of each course is recorded. For all deflection angles over 4° it is good practice to figure and run in on the ground the desired curve. Curves with central angles of less than 4° can be run in with the eye during construction.

The center line is marked at intervals of either fifty or one hundred feet (see cross-section, page 121) in any convenient manner; the alignment of these points should be correct to within 0.2 and the distance along the line to within 0.1 per 100 feet of the length; any attempt to get more accurate stationing is a waste of time. The chaining may be done on the surface of the ground up to a grade of 5 per cent with no objectionable error; beyond that slope, however, the tape should be leveled and plumbed. Steel tapes should be used for chaining the center line and referencing the hubs.

A convenient method of marking the actual center-line stations is to use a nail and piece of flannel; red flannel for the 100′ stations and white flannel for the intermediate 50′ stations, if needed. Where the soil is sandy, or muddy, and these nails would be kicked out or covered, a line of stakes can be set outside of the traveled way on a specific offset from the center line. However, if an offset line is used the chaining of all curves should be done on the center line to insure a correct center-line distance and the stakes placed radially on the desired offset. Railroad

spikes make good permanent transit points and are easily placed.

At the same time that the line is run it is just as well to paint the 100′ station numbers on any convenient place where they can be readily seen, as stations marked in this manner make it much easier to sketch in the topography than if marked in chalk on stakes. Also, if the stations are permanently marked it is easier for the construction engineer to pick up the transit points at some future time.

A party of five men will run from two to four miles of center line a day, the speed depending upon the number of curves and length of tangents, if the hubs have been previously placed and referenced. If the hubs are placed at the same time the line is run, the work is greatly delayed.

Two men can place and reference the transit points at the tangent intersections at the rate of from four to ten miles per day.

Sta.	B. S. +	F. S. −	H. I.	Elev.	
B.M.#1				402.76	Spike in 15″ Elm, Right of Sta. 5+60
	7.21	6.10	409.97	403.87	
	4.20	3.48	408.07	404.59	
B.M.#2	9.19	1.16	413.78	412.62	Top of Stone Hitching Post, Left. Sta. 15+00

Fig. 44. — Bench Level Notes

Levels and Cross-Sections. Bench levels are run in the usual manner; the levels will be sufficiently accurate if the rod is read to the nearest 0.01′; for such work any good level and a self-reading rod graduated to hundredths are satisfactory. Benches are established at intervals of 1,000–1,500 feet; they must be substantial, well marked, and so situated as not to be disturbed during construction. A small railroad spike in the root of a tree, a large boulder, or the water table of a building make good benches.

The bench levels may be referred to some local datum in general use or to the U. S. levels, or the datum can be assumed.

In running bench levels it is better to use each bench as a turning point, as side-shot benches may be wrong even if the line of levels is correct.

Cross-sections are taken at either 100′ or 50′ intervals, at all culverts, possible new culvert sites, and any intermediate breaks not shown by the normal interval. Enough sections are taken to show the constantly changing shape of the road.

The distance of the shots from the center line of the road is read to the nearest 1.0′ where the ground has no abrupt change of slope and to the nearest 0.5′ where there is a well-defined abrupt change. The elevations are read to the nearest 0.1′. The sections should extend from fence line to fence line, or in villages from sidewalk to sidewalk, and the position of the pole lines, tree lines, curbs, etc., noted. Engineers differ as to whether the sections should be taken at a normal interval of 50′ or 100′.

Table 27 gives the difference in the computed quantity of earthwork using 50′ and 100′ sections with intermediate sections at well-defined breaks in the grade.

TABLE 27

Name of Road	Length Figured	Character of Road	Excavation 50′ Section	Excavation 100′ Section	Approximate Difference	Per cent of Difference
			Cu. Ft.	Cu. Ft.	Cu. Ft.	
Scottsville Mumford ...	1 mile	flat	61,444	61,995	550	+ $\frac{9}{10}$%
Scottsville Mumford ...	1 "	hilly	111,109	111,700	600	+ $\frac{1}{2}$ %
Leroy Caledonia	1 "	rolling	57,840	60,560	2700	+ $4\frac{3}{4}$ %
*Leroy Caledonia	$\frac{3}{4}$ "	flat	77,841	78,659	800	+ 1 %
Clarence Center	1 "	rolling	73,727	73,048	700	− 1 %
Clarence Center	1 "	flat	38,037	39,415	1400	+ $3\frac{7}{10}$%
Lockport Tonawanda ...	1 "	flat	59,096	59,470	400	+ $\frac{7}{10}$%
*East Henrietta Rochester	1 "	rolling	37,275	36,075	1200	− $3\frac{1}{4}$ %

The following tabulation shows the variation for shorter sections of the starred roads.

Name of road and Station to Station	Quantities by 50′ Sections	Quantities by 100′ Sections	Approximate Difference	Per cent of Difference
	Cu. Ft.	Cu. Ft.	Cu. Ft.	
Leroy				
Caledonia, 80– 90 . . .	19,151	19,525	400	+ 2 %
" 90–100 . . .	21,915	23,415	1500	+ 7 %
" 100–110 . . .	21,555	20,689	900	− 4 %
" 110–120 . . .	15,220	15,030	200	− $1\frac{3}{10}$ %
Total and averages .	77,841	78,659	800	+ 1 %
East Henrietta				
Rochester, 0–19 . . .	14,625	14,300	300	− 2 %
" 32–49 . . .	11,950	11,575	350	− 3 %
" 49–66 . . .	10,700	10,200	500	− 5 %
Total and averages .	37,275	36,075	1200	− $3\frac{1}{4}$ %

The question of quantities is not the only factor in determining the interval. Where it is important to fit the local conditions, as in a village, or to utilize an old hard foundation, the designer is helped by 50′ sections.

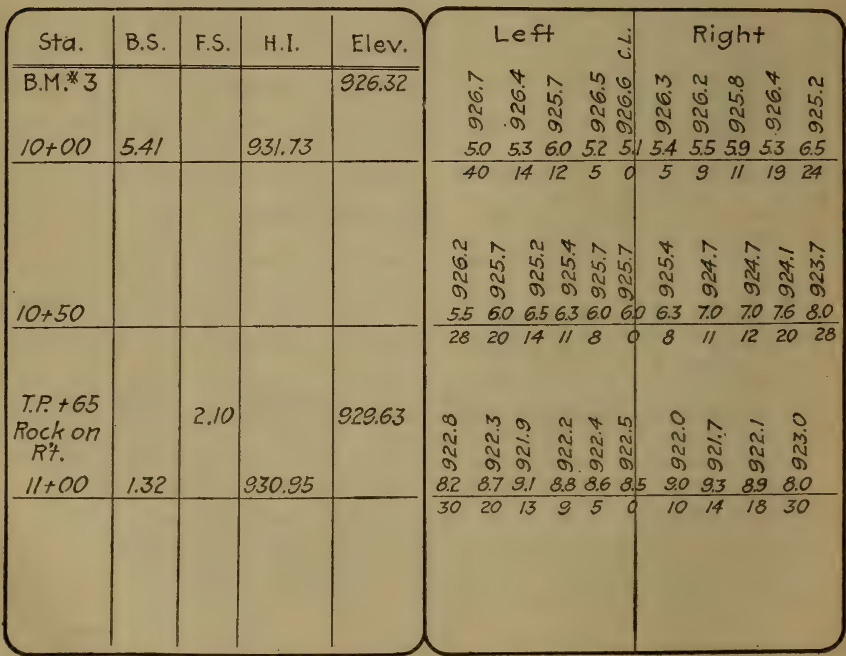


Fig. 45. — Cross-Section Notes

In taking cross-sections the work becomes mechanical, and unless the engineer in charge is unusually alert to all the intermediate changes better results will be obtained by the use of the shorter interval. For these reasons the author believes that a 50′ interval is advisable except on long uniform stretches of road.

A party of three men will run from 4,000 to 7,000 feet of 50′ cross sections per day; a party of four men from 5,000 to 9,000 feet, depending on the country.

DRAINAGE

The drainage notes show the position and size of all the existing culverts; the area of the watersheds draining to them and a

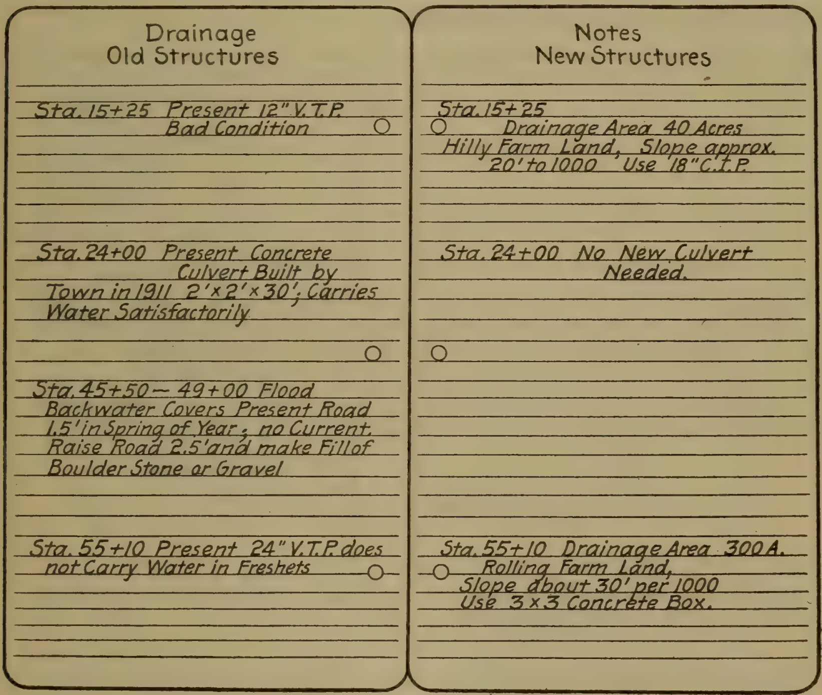


FIG. 46

recommendation of the size culvert to be built; the location, drainage area, and size of desirable new culverts; the necessity for outlet ditches and their length, if required; the elevation of flood water near streams, and the condition of the abutments and superstructure of long-span bridges. The cross-section levels are supplemented to show these points fully. Where the U. S. geological maps are available the areas of watersheds can be easily determined; where no such maps have been made the drainage areas can be easily mapped with a small 15″ plane table

oriented with a magnetic needle; the distances can be paced and the divides determined with a hand level. One inch to 2,000 feet is a convenient scale.

The drainage scheme should be carefully worked out by the Chief of Party, as the possibilities of friction with local people are greater on this part of the design than any other. In the chapter on Drainage this fact was mentioned and designers were cautioned not to use new culverts unless necessary.

TOPOGRAPHY

The topography notes show the features of the adjacent territory that might affect the design. These include the location of buildings, drives, intersecting roads, streams, railroads, poles, trees, sidewalks, crosswalks, and property lines. The names of property owners are recorded.

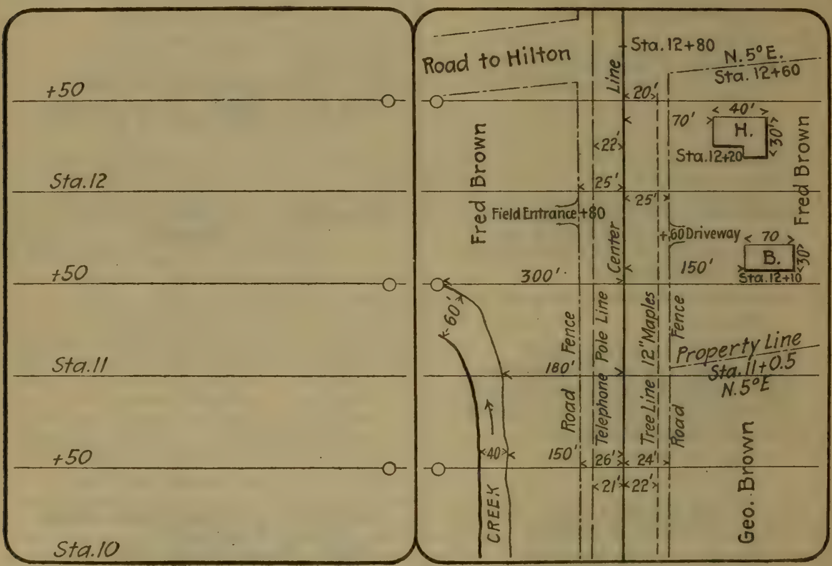


FIG. 47

A simple method of locating these points is to refer them directly to the previously run center line by right-angle offsets; such notes are easily taken and quickly plotted.

In taking the topography the plus stationing along the center line and the offset distances to all points inside of the road fences should be measured by tape to the nearest foot; the distances to and the dimensions of buildings, etc. outside of these limits, can be paced or estimated; the bearings of the property lines can be read near enough with a pocket compass, except for Right of Way surveys which are described on page 154.

The instruments needed for work of this kind are a pocket compass reading to 2°, steel picket, and metallic tape.

Two experienced men will take from two miles to four miles of topography a day except in villages, where from one half to a mile is average speed.

DIRECTION AND AMOUNT OF TRAFFIC is determined by inspection and inquiry of the residents along the road.

To illustrate the information required, an extract from the survey report of the Fairport Nine Mile Point Road is given below:

FAIRPORT NINE MILE POINT ROAD TRAFFIC REPORT

Heavy Hauling. The direction of heavy hauling on this road is approximately as follows:

1.	Station No.	195	to station	0	towards	Fairport.
2.	"	195	"	400	"	Webster.
3.	"	580	"	400	"	"

This divides the road into three sections for the determination of the ruling grades.

The ruling grade for section 1 will be determined by the hills at station 10 and station 48 and probably will be limited to 5 per cent.

The ruling grade for section 2 will be determined by the knolls at stations 267, 285, and 300.

The ruling grade for section 3 will be determined by the hills at stations 445 and 494.

The team traffic is medium heavy station 90 to station 0; light, station 270 to 90; medium, station 270 to 375; heavy, station 375 to 386; very heavy, equivalent to city street, station 386 to 408; medium heavy, station 408 to 450, and light, station 450 to 580. Macadam construction will not be suitable stations 386 to 408.

The automobile pleasure traffic will be largely through traffic and probably fairly heavy.

FOUNDATION SOILS

The notes on soils show the character, width, and depth of the existing surfacing material and the kind of underlying material. This feature of the survey is important, as it governs the thickness of the bottom course, and, to a certain extent, the position of the grade line where an existing solid foundation can be utilized and the thickness of the improved road reduced to a minimum.

Even with a careful soil examination it is impossible to make the design of the foundation definite, as mentioned on page 73, but the quantity of the material that will be needed can be estimated very closely.

The subsoil can be readily examined by driving a $1\frac{1}{2}''$ or $1''$ steel bar to the required depth, which is usually not over $4.0'$ to $5.0'$ even in cuts, removing the bar and replacing with a $\frac{3}{4}''$ gas pipe, which is driven a few inches and withdrawn. The core will give a fair idea of the material to be encountered.

Soil Notes				Foundation Recommendations
Sta. to Sta.		Surface Mat.	Sub Surface	
0	30	Sand & Gravel	Sand & Gravel	Total Thickness Metalling 6"
30	31	Clay & Gravel	Clay 1' down	" " " 9"
31	36	Clay	Clay	" " " 12"
36	40	Gravel 8" deep	Wet Clay	Underdrain on Rt Stone 15" deep
40	41	" 4" "	Clay Loam	Fill at this Point " 6" "

FIG. 48

Where rock is encountered the elevation of the outcrop is shown, and if the rock underlies the road for any distance within two or three feet of the surface this depth is determined by driving bars. Sample notes below:

Station	Left	Center Line	Right
62	$\frac{3.5'}{20}$	$\frac{2.5'}{00}$	$\frac{0.5'}{20}$
63	$\frac{1.5'}{25}$	$\frac{1.2'}{00}$	$\frac{1.0'}{22}$

The note $\frac{3.5'}{20}$ means that 20′ to the left of the proposed center line of the improvement, the rock is 3.5′ below the present surface; from these notes the rock can be readily plotted on the cross-sections. Its character can be determined from adjacent outcrops, or from test pits, if required.

LOCATION AND CHARACTER OF MATERIALS

The selection of materials and the estimate of the construction cost depend on a knowledge of the available materials and their location relative to the road.

Unloading Points for Freight. Provided U. S. geological maps are obtainable, the position of sidings may be marked on the sheets. The notes for each siding show its car capacity; whether or not an elevator unloading plant can be erected, and if hand unloading is necessary whether teams can approach from one side or two. They should also show any coal trestles that can be utilized in unloading, and the location and probable cost of any new sidings that will materially reduce the length of the haul. Canal or river unloading points are shown in the same manner.

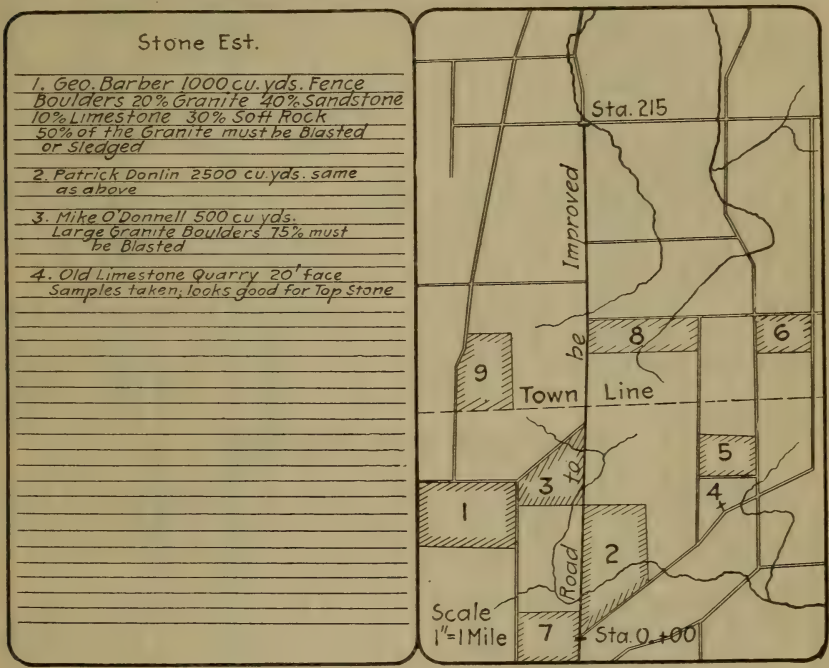


FIG. 49

Sand, Gravel, and Filler Material. The position of sand and gravel pits and filler material are noted with their cost at the pit; if no local material is available the cost f.o.b. at the nearest siding is given.

Stone Supply. Provided imported stone is to be used the work is simplified to determining the rate f.o.b. to the various sidings for the product of the nearest commercial stone-crushing plant that produces a proper grade of stone.

In case local stone is available the location of the quarries or outcrops is shown; the amount of stripping, if any, and the cost of quarry rights. If the estimate will depend upon rock owned by a single person an option is obtained to prevent an exorbitant raise in price.

In the case of field or fence stone a careful estimate is made of the number of yards of boulder stone available, the owners'

names, what they will charge for it, the position of the fences or piles relative to the road, or side roads, and if the fences are not abutting on a road or lane the length of haul through fields to the nearest road or lane. As fences are usually a mixture of different kinds of rock, the engineer estimates the percentage of granite, limestone, sandstone, etc., and the percentage that will have to be blasted or sledged in order to be crushed by an ordinary portable crusher. The amount of field stone required per cubic yard of macadam is given in estimates, page 274. If there is a large excess of stone a careful estimate need not be made, only enough data being collected to determine the probable position of the crusher set-ups and the average haul to each set-up. If a sufficient supply is doubtful a close estimate is made as outlined above and options obtained from the various owners.

Samples of the different rocks are tested. (See materials.)

Preliminary surveys of the above description should be made at a speed of from two to four miles per week at a cost of from $35 to $70 per mile, allowing $6 per day for the engineer; $3.50 for the instrument man; $2 per man for three laborers; $1 per day board per man and $4 per day for livery.

Right of Way and diversion line surveys are often needed but are usually not made at this time; if the designer believes that additional land must be acquired or that a diversion line is necessary, he indicates the information desired and the surveys are made.

RIGHT OF WAY SURVEYS

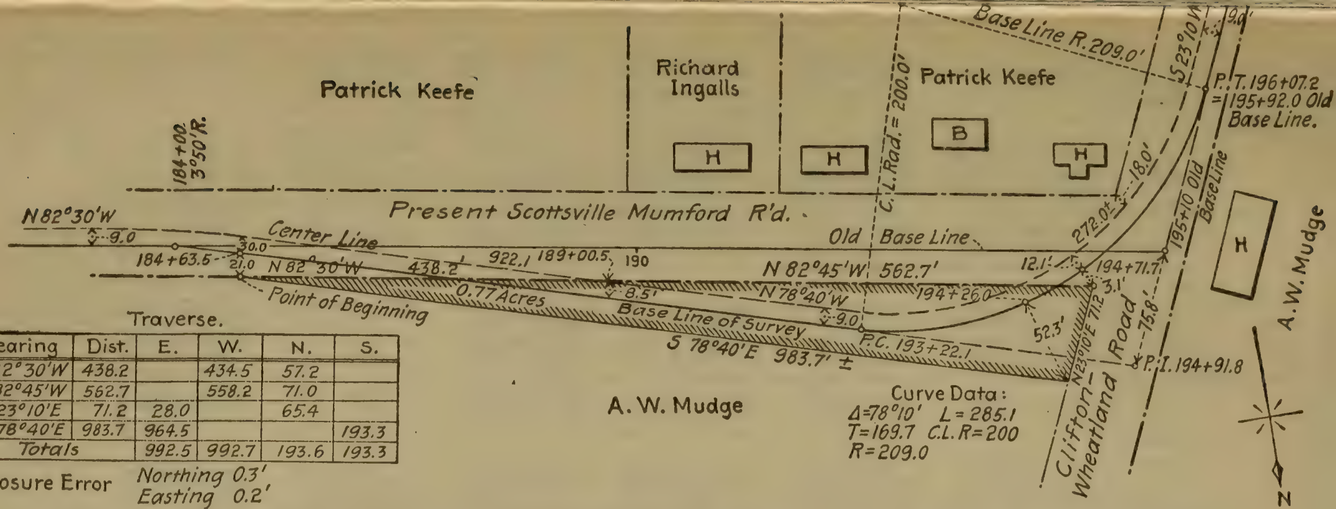
These surveys are used not only to show the amount of land to be acquired but, also, the damage to property from altering the shape of a field, cutting a farm in two, changing the position of a house or barn relative to the road, etc.

The acreage to be taken is shown by an ordinary land survey in which the road lines, property lines, corners, etc., are located in relation to the proposed center line of the improvement, and their lengths and bearings carefully determined. It is often difficult to locate the road boundaries, as town records are carelessly kept and there is a general tendency to encroach on the road. As the amount paid for new Right of Way is rarely settled on an acreage basis, it is customary to take the existing fence lines as the road line unless it is very evident that the fence has been moved. This produces better feeling on the part of the property owner and does not affect the price paid. The lines between adjoining properties are usually well defined.

In cases where an orchard is damaged the position and size of the trees are noted; where a field or farm is cut the whole field is shown, with the shape and acreage of the pieces remaining after the land actually appropriated has been taken out.

As is usually done in all land surveys, the parcel to be bought is traversed and the survey figured for closure error to insure the description against mistakes.

The standard form of map and description of the N. Y. State Department is shown in the following illustration:



Traverse.

Bearing	Dist.	E.	W.	N.	S.
N82°30'W	438.2		434.5	57.2	
N82°45'W	562.7		558.2	71.0	
N23°10'E	71.2	28.0		65.4	
S 78°40'E	983.7	964.5			193.3
Totals		992.5	992.7	193.6	193.3

Closure Error Northing 0.3' Easting 0.2'

FIG. 50. — Land to be Acquired for the Scottsville-Mumford State Highway, Monroe County: Route No. 16, Section No. 1, from A. W. Mudge.

All that piece or parcel of land situate in the Town of Wheatland, County of Monroe, State of N.Y., for the Scottsville-Mumford State Highway, as shown on the accompanying map and described as follows:—

Beginning at a point in the northerly boundary of the existing Scottsville-Mumford highway, 21.0 feet northerly, measured at right angles, from station 184+63.5 of the survey base line of the proposed Scottsville-Mumford State Highway (Route No. 16, Section No. 1), and 30.0 feet distant northerly, measured at right angles, from the hereinafter described center line of the said proposed State highway; thence N. 82° 30′ W., along the northerly boundary of the said existing Scottsville-Mumford Highway; 438.2 feet, to a point 8.5 feet distant, southerly, measured at right angles, from station 189+00.5 of the said base line; thence N. 82°45′ W. along the northerly boundary of the said highway, 562.7 feet; to a point 3.1 feet distant northwesterly, measured radially, from station 194+71.7 of the said base line and 12.1 feet distant; measured radially, from the said center line; thence N. 23° 10′ E. along the easterly boundary of the existing Wheatland-Clifton Highway, 71.2 feet to a point 52.3 feet distant northerly, measured radially from station 194+26 of the said base line; thence S. 78° 40′ E. 983.7 ± feet to the point of beginning; being 0.77 acres more or less.

The above mentioned center line is a portion of the center line of the said proposed Scottsville-Mumford State Highway (Route No. 16, Section No. 1) as shown on a map on file in the office of the Clerk of Monroe County, and is described as follows:—

Beginning at a point 9.0 feet distant southerly, measured at right angles, from Station 183+00 of the said base line; thence N. 82° 30′ W. 100 feet; thence N. 78° 40′ W. 922.1 feet; thence curving to the left with a radius 200 feet; 272 ± feet to a point 9.0 feet distant southeasterly, measured radially, from Station 196+07.2 of the said base line (=195+92.0 old base line) thence S. 23° 10′ W.

TABLE 28.[1] HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS

Minutes	0°		1°		2°		3°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	100.00	0.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	0.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	0.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	0.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100.00	0.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	0.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	0.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	0.41	99.95	2.15	99.85	3.90	99.68	5.63
16	100.00	0.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	0.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	0.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	0.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	0.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	0.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	0.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	0.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	0.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	0.99	99.93	2.73	99.80	4.48	99.62	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
c = 0.75	0.75	0.01	0.75	0.02	0.75	0.03	0.75	0.05
c = 1.00	1.00	0.01	1.00	0.03	1.00	0.04	1.00	0.06
c = 1.25	1.25	0.02	1.25	0.03	1.25	0.05	1.25	0.08

[1] From "Theory and Practice of Surveying," by Prof. J. B. Johnson, New York: John Wiley & Sons. We are enabled to use this form through the courtesy of Prof. J. B. Johnson.

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—*Continued*

	4°		5°		6°		7°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67
58	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
c = 0.75	0.75	0.06	0.75	0.07	0.75	0.08	0.74	0.10
c = 1.00	1.00	0.08	0.99	0.09	0.99	0.11	0.99	0.13
c = 1.25	1.25	0.10	1.24	0.11	1.24	0.14	1.24	0.16

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	8°		9°		10°		11°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
38	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34
c = 0.75.	0.74	0.11	0.74	0.12	0.74	0.14	0.73	0.15
c = 1.00.	0.99	0.15	0.99	0.16	0.98	0.18	0.98	0.20
c = 1.25.	1.23	0.18	1.23	0.21	1.23	0.23	1.22	0.25

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	12°		13°		14°		15°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
c = 0.75	0.73	0.16	0.73	0.17	0.73	0.19	0.72	0.20
c = 1.00	0.98	0.22	0.97	0.23	0.97	0.25	0.96	0.27
c = 1.25	1.22	0.27	1.21	0.29	1.21	0.31	1.20	0.34

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	16°		17°		18°		19°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
6	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
16	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
22	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
26	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
36	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
56	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
60	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
c = 0.75	0.72	0.21	0.72	0.23	0.71	0.24	0.71	0.25
c = 1.00	0.96	0.28	0.95	0.30	0.95	0.32	0.94	0.33
c = 1.25	1.20	0.35	1.19	0.38	1.19	0.40	1.18	0.42

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	20°		21°		22°		23°	
Minutes.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85.52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32.80	86.57	34.10	85.36	35.36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.31	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83.97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86.33	34.35	85.11	35.60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	36.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16
c = 0.75 .	0.70	0.26	0.70	0.27	0.69	0.29	0.69	0.30
c = 1.00 .	0.94	0.35	0.93	0.37	0.92	0.38	0.92	0.40
c = 1.25 .	1.17	0.44	1.16	0.46	1.15	0.48	1.15	0.50

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	24°		25°		26°		27°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff Elev.	Hor. Dist.	Diff. Elev.
0	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
2	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
4	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
6	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
8	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
10	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
12	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66
14	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69
16	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
18	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
20	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
22	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
24	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
26	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
28	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
30	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
32	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99
34	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
36	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06
38	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
40	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
42	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
44	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
46	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
48	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
50	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
52	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
54	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
56	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
58	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
60	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45
c = 0.75	0.68	0.31	0.68	0.32	0.67	0.33	0.66	0.35
c = 1.00	0.91	0.41	0.90	0.43	0.89	0.45	0.89	0.46
c = 1.25	1.14	0.52	1.13	0.54	1.12	0.56	1.11	0.58

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	28°		29°		30°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	77.96	41.45	76.50	42.40	75.00	43.30
2	77.91	41.48	76.45	42.43	74.95	43.33
4	77.86	41.52	76.40	42.46	74.90	43.36
6	77.81	41.55	76.35	42.49	74.85	43.39
8	77.77	41.58	76.30	42.53	74.80	43.42
10	77.72	41.61	76.25	42.56	74.75	43.45
12	77.67	41.65	76.20	42.59	74.70	43.47
14	77.62	41.68	76.15	42.62	74.65	43.50
16	77.57	41.71	76.10	42.65	74.60	43.53
18	77.52	41.74	76.05	42.68	74.55	43.56
20	77.48	41.77	76.00	42.71	74.49	43.59
22	77.42	41.81	75.95	42.74	74.44	43.62
24	77.38	41.84	75.90	42.77	74.39	43.65
26	77.33	41.87	75.85	42.80	74.34	43.67
28	77.28	41.90	75.80	42.83	74.29	43.70
30	77.23	41.93	75.75	42.86	74.24	43.73
32	77.18	41.97	75.70	42.89	74.19	43.76
34	77.13	42.00	75.65	42.92	74.14	43.79
36	77.09	42.03	75.60	42.95	74.09	43.82
38	77.04	42.06	75.55	42.98	74.04	43.84
40	76.99	42.09	75.50	43.01	73.99	43.87
42	76.94	42.12	75.45	43.04	73.93	43.90
44	76.89	42.15	75.40	43.07	73.88	43.93
46	76.84	42.19	75.35	43.10	73.83	43.95
48	76.79	42.22	75.30	43.13	73.78	43.98
50	76.74	42.25	75.25	43.16	73.73	44.01
52	76.69	42.28	75.20	43.18	73.68	44.04
54	76.64	42.31	75.15	43.21	73.63	44.07
56	76.59	42.34	75.10	43.24	73.58	44.09
58	76.55	42.37	75.05	43.27	73.52	44.12
60	76.50	42.40	75.00	43.30	73.47	44.15
$c = 0.75$	0.66	0.36	0.65	0.37	0.65	0.38
$c = 1.00$	0.88	0.48	0.87	0.49	0.86	0.51
$c = 1.25$	1.10	0.60	1.09	0.62	1.08	0.64

Diversion Line Surveys. Where there is no doubt as to the grade to be adopted, or the alignment to be used, the location is made directly in the field and the center line is run and the cross sections taken in the same manner as for a preliminary survey. If, however, the country is badly cut up and it is difficult to make a field location direct, a transit stadia survey is made covering the territory that will include all the possible locations and from the resulting contour map the different locations are projected and approximate estimates figured. The adopted line is then run in the field, cross sections taken in the usual manner and an accurate estimate made. This method is used so seldom that the author does not feel justified in giving space to the theory of stadia measurements or the methods of stadia surveys. If the reader is not familiar with this class of work he is referred to the standard works on surveying.

A convenient scale for a contour map for the projection work mentioned above is $1'' = 20'$ with a contour interval of $1'$ to $5'$, depending on the country. Table 28 is useful for reducing stadia notes. For a small number of shots this table and a slide rule will answer the purpose; for any extended amount of work a stadia reduction diagram or Noble & Casgrain's tables are recommended.

If the stadia work is well done very satisfactory projections can be made.

ADJUSTMENT OF INSTRUMENTS

Wye Level. *To make the line of collimation parallel to the telescope rings.* Level the instrument roughly. Loosen the Y clamps so the telescope can turn freely in them; clamp the horizontal motion and by means of the leveling screws and tangent motion bring the intersection of the cross hairs on some well-defined point. Then, without lifting from the Ys, turn the telescope over 180° watching to see if the cross wires remain on the point during the operation; if they do the adjustment is correct; if they do not, correct $\frac{1}{2}$ the apparent error for both vertical and horizontal wires by means of the cross hair ring, adjusting screws, and repeat until the wires remain on the point for a complete revolution.

To make the longitudinal axis of the level bubble parallel to the plane of the line of collimation. Level the machine over either pair of leveling screws; unclamp the Ys; rotate the telescope in the Ys until the bubble tube is on one side of the bar. If the bubble remains in the center the adjustment is correct. If it runs from the center bring it to its correct position by means of the sidewise adjusting screw at one end of the bubble case.

To make the bubble parallel to the rings and line of collimation. Level the machine; unclamp the Ys; lift the telescope carefully from the Ys and reverse end for end; if the bubble runs to the center after the telescope has been reversed the adjustment is correct; if not, correct $\frac{1}{2}$ the error by means of the adjusting

nuts on the bubble case and ½ the error with the leveling screws and repeat the test until the bubble remains in the center.

To adjust the Ys so the level bubble will be at right angles to the axis of the instrument. Level the machine approximately over both sets of screws; level carefully over one set; rotate on the spindle 180°; if the bubble remains in the center the adjustment is correct; if not, correct ½ the error by means of the adjusting nuts on the Ys and ½ by the leveling screws. Repeat until the bubble remains in the center when reversed over either pair of leveling screws.

To test the horizontal wire. Be sure that the pin in the Y clamp is in the notch of the telescope ring to keep the telescope from rotating; level the machine and compare the horizontal wire with any level line; if the wire is not level loosen the cross wire ring and turn to the correct position. Adjust again for collimation and the level adjustments are complete.

Dumpy Level.

To make the bubble perpendicular to the axis of the instrument. Level the machine roughly over both sets of leveling screws and carefully over one set; rotate on the pinion 180°; if the bubble stays in the center the adjustment is correct; if not, correct ½ the error by means of the bubble adjusting nut and ½ by the leveling screws, and repeat until correct.

To make the horizontal line of collimation parallel to the level bubble. Level the machine; drive a stake about 150′ or 200′ from the instrument and set the level rod target by the horizontal wire; rotate the instrument 180° and set another stake at the same distance from the machine as the first one; drive it until a rod reading taken on it is the same as the reading on the first stake. These stakes will then be level even though the machine is out of adjustment. Then set the level up near one of the stakes; level carefully and take rod readings on both; if these readings are the same the level is in adjustment; if not, correct the position of the horizontal wire by means of the cross wire ring screws until the readings on both stakes are the same.

Test the horizontal wire on a level line in the same manner as for the Y level.

Transit.

Plate levels. Level the machine with each plate level bubble parallel to one set of leveling screws; rotate on the spindle 180°; if the bubbles remain in the center the adjustment is correct; if not, correct ½ the error with the bubble adjusting screws and ½ with the leveling screws. Repeat until correct.

Line of collimation, ordinary distances. Level the machine; clamp the horizontal motion; with the slow motion screw, set the vertical cross wire on some well-defined point 500 or 600 feet away; transit the telescope and set a mark the same dis-

tance in the opposite direction; then rotate the machine on the spindle, set on the first mark and transit the telescope; if the vertical wire strikes the second point the adjustment is correct; if not, correct $\frac{1}{4}$ the error by means of cross wire ring adjusting screws and repeat until correct.

To make the standards the same height. Level the machine carefully; set the vertical wire on some well-defined point as high as can be seen; bring the telescope down and set a point; rotate the machine 180°; transit the telescope set on the low point and raise the telescope; if the wire bisects the original high point the adjustment is correct; if not, correct $\frac{1}{2}$ the error by means of the standard adjusting screw.

Test the vertical wire by means of a plumb line to see that it is vertical; if not, loosen the cross hair ring and turn to the correct position; test again for collimation.

If the transit is to be used as a level make the level bubble parallel to the horizontal wire by the two-peg method in the same manner as described for the Dumpy level.

EXPLANATION OF CURVE TABLES AND DEVELOPMENT OF CURVE FORMULAE

Curves for roadwork need not be as carefully worked out as in railroad surveying. Except for long curves the external is usually measured and the curve run in by the eye, and for this reason many of the tables given in the railway field manuals are omitted and those used are tabulated in a different form.

Table No. 29, *Radii of curves.* The curve radii are computed on a basis of 5,730 feet as the radius of a one-degree curve and are inversely proportional to the degree of curvature; they are tabulated to the nearest 0.1′. The usual columns showing logarithm of radius, tangent offset and middle ordinate are replaced by the deflection angle per foot of arc, per 25′ of arc, and per 50′ of arc, which saves considerable time in the computation of deflections. These values are tabulated only for even degree, twenty-minute, thirty-minute, and forty-minute curves, as there is always sufficient leeway both in the external and tangent to select a suitable curve from this list.

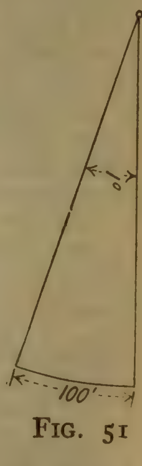


FIG. 51

Table No. 30, *Functions of* 1° *curve.* Column 1 gives the central angle $\triangle$ for every 10 minutes from 0° to 4°, every minute 4° to 100°, and every 10 minutes 100° to 120°.

Column 2 gives the same central angle as in column 1 expressed in decimals of a degree. This simplifies figuring the curve length.

Columns 3 and 4 give the tangent and external for the central angles of column 1 to the nearest 0.1′. By the use of the chord lengths recommended at the top of each page of this table no correction need be made for tangent length or external distance

of any desired curve, figured by dividing the value given in the table by the degree of curvature required.

The error that is introduced by the use of these chords is less than 0.1′ per 100′, which is the allowable limit of error in chaining center line.

For the convenience of readers not familiar with the theory of curves and the computation of curve notes, the following brief demonstration is made:

RADII OF CURVES AND DEGREE OF CURVATURE

A one-degree curve is defined as a curve having such a radius that 100 feet of arc will subtend a one-degree central angle.

There are 360° of central angle for a complete circle. The circumference of a circle is expressed by the formula $2\pi R$. Therefore the radius of a one-degree curve is determined by the formulæ

$$2\pi R = 360 \times 100$$

$$R = \frac{36000}{2\pi} = \frac{36000}{2(3.14159)} = 5729.6 \text{ feet} \quad . \quad . \quad . \quad (1)$$

TABLE 29. RADII AND DEFLECTIONS

Figured on a basis of R = 5730′ for a 1° curve.

Degree of Curve	Radius of Curve	Deflection per foot of Arc	Deflection per 25′ of Arc		Deflection per 50′ of Arc	
	Feet	Minutes	Deg.	Minutes	Deg.	Minutes
0° 30′ . .	11,460.0	00.15	—	—	0	07.5
0° 40′ . .	8.595.0	00.2	—	—	0	10.0
0° 50′ . .	6,876.0	00.25	—	—	0	12.5
1° 00′ . .	5,730.0	00.3	—	—	0	15.0
1° 20′ . .	4,297.5	00.4	—	—	0	20.0
1° 30′ . .	3,820.0	00.45	—	—	0	22.5
1° 40′ . .	3,438.0	00.5	—	—	0	25.0
2° 00′ . .	2,865.0	00.6	—	—	0	30.0
2° 20′ . .	2,455.7	00.7	—	—	0	35.0
2° 30′ . .	2,292.0	00.75	—	—	0	37.5
2° 40′ . .	2,148.8	00.8	—	—	0	40.0
3° 00′ . .	1,910.0	00.9	—	—	0	45.0

TABLE 29. — *Continued*

Degree of Curve	Radius of Curve	Deflection per foot of Arc	Deflection per 25′ of Arc		Deflection per 50′ of Arc	
	Feet	Minutes	Deg.	Minutes	Deg.	Minutes
3° 20′ . .	1,719.0	01.0	—	—	0	50.0
3° 30′ . .	1,637.1	01.05	—	—	0	52.5
3° 40′ . .	1,562.7	01.1	—	—	0	55.0
4° 00′ . .	1,432.5	01.2	—	—	1	00.0
4° 20′ . .	1,322.3	01.3	—	—	1	05.0
4° 30′ . .	1,273.3	01.35	—	—	1	07.5
4° 40′ . .	1,227.9	01.4	—	—	1	10.0
5° 00′ . .	1,146.0	01.5	—	—	1	15.0
5° 30′ . .	1,041.8	01.65	—	—	1	22.5
6° 00′ . .	955.0	01.8	—	—	1	30.0
6° 30′ .	881.5	01.95	—	—	1	37.5
7° 00′ .	818.6	02.1	—	—	1	45.0
7° 30′ . .	764.0	02.25	—	—	1	52.5
8° 00′ . .	716.3	02.4	—	—	2	00.0
8° 30′ . .	674.1	02.55	—	—	2	07.5
9° 00′ . .	636.6	02.7	—	—	2	15.0
9° 30′ . .	603.2	02.85	—	—	2	22.5
10° 00′ . .	573.0	03.0	—	—	2	30.0
10° 30′ . .	545.7	03.15	—	—	2	37.5
11° 00′ . .	520.9	03.3	—	—	2	45.0
11° 30′ . .	498.3	03.45	—	—	2	52.5
12° 00′ . .	477.5	03.6	—	—	3	00.0
12° 30′ . .	458.4	03.75	—	—	3	07.5
13° 00′ . .	440.8	03.9	—	—	3	15.0
13° 30′ . .	424.4	04.05	—	—	3	22.5
14° 00′ . .	409.3	04.2	—	—	3	30.0
14° 30′ . .	395.2	04.35	—	—	3	37.5
15° 00′ . .	382.0	04.5	—	—	3	45.0
15° 30′ . .	369.6	04.65	—	—	3	52.5
16° 00′ . .	358.1	04.8	2	00.0	4	00.0
16° 30′ . .	347.3	04.95	2	03.8	4	07.5
17° 00′ . .	337.0	05.1	2	07.5	4	15.0
17° 30′ . .	327.4	05.25	2	11.2	4	22.5
18° 00′ . .	318.3	05.4	2	15.0	4	30.0
18° 30′ . .	309.7	05.55	2	18.7	4	37.5

TABLE 29. — *Continued*

Degree of Curve	Radius of Curve	Deflection per ft. of Arc	Deflection per 25′ of Arc		Deflection per 50′ of Arc	
		Minutes	Degree	Minutes		
19° 00′	301.6	05.7	2	22.5		
19° 30′	293.8	05.85	2	26.2		
20° 00′	286.5	06.0	2	30.0		
20° 30′	279.5	06.15	2	33.7		
21° 00′	272.9	06.30	2	37.5		
21° 30′	266.5	06.45	2	41.2		
22° 00′	260.5	06.6	2	45.0		
22° 30′	254.7	06.75	2	48.7		
23° 00′	249.1	06.9	2	52.5		
23° 30′	243.8	07.05	2	56.2		
24° 00′	238.8	07.2	3	00.0		
24° 30′	233.9	07.35	3	03.7		
25° 00′	229.2	07.5	3	07.5		
26° 00′	220.4	07.8	3	15.0		
27° 00′	212.2	08.1	3	22.5		
28° 00′	204.6	08.4	3	30.0		
29° 00′	197.6	08.7	3	37.5		
30° 00′	191.0	09.0	3	45.0	Deflection per 10′ of Arc	
31° 00′	184.8	09.3	3	52.5		
32° 00′	179.1	09.6	4	00.0	1°	36′
33° 00′	173.6	09.9	—	—	1°	39′
34° 00′	168.5	10.2	—	—	1°	42′
35° 00′	163.7	10.5	—	—	1°	45′
36° 00′	159.2	10.8	—	—	1°	48′
37° 00′	154.9	11.1	—	—	1°	51′
38° 00′	150.8	11.4	—	—	1°	54′
39° 00′	146.9	11.7	—	—	1°	57′
40° 00′	143.2	12.0	—	—	2°	00′
42° 00′	136.4	12.6	—	—	2°	06′
44° 00′	130.2	13.2	—	—	2°	12′
46° 00′	124.6	13.8	—	—	2°	18′
48° 00′	119.4	14.4	—	—	2°	24′
50° 00′	114.6	15.0	—	—	2°	30′
52° 00′	110.2	15.6	—	—	2°	36′
54° 00′	106.1	16.2	—	—	2°	42′
56° 00′	102.3	16.8	—	—	2°	48′

For all practical purposes the value of 5,730 can be used.

In the same manner a two-degree curve is one having such a radius that 100 feet of arc will subtend two degrees of central angle, and its radius is

$$2\pi R = \frac{360}{2} \times 100$$

$$R = \frac{18000}{2\pi}$$

or $\frac{1}{2}$ of the radius of a one-degree curve.

The radius of a three-degree curve will be $\frac{1}{3}$ of 5,730.

The radius of a four-degree curve will be $\frac{1}{4}$ of 5,730.

The formula for the radius of any degree of curve is therefore

$$R = \frac{5{,}730}{D.} \qquad (2)$$

The degree of curvature for any specified radius is therefore

$$D = \frac{5{,}730}{R.} \qquad (3)$$

In general the degree of curvature is expressed by the central angle subtended by 100 feet of arc, and the radius for that degree of curve is found by dividing 5,730 feet, the radius of a one-degree curve, by the degree of curve desired expressed in degrees and decimals of a degree. That is, if the radius of a 3° 30′ curve is wanted, divide 5730 by 3.5, which equals 1637.1′. The radii given in Table No. 29 are computed in this manner.

Length of curve. For a 5° curve a central angle of 5° subtends 100′ of arc; a central angle of 10°, 200′ of arc; a central angle of 12° 30′, 250′ of arc. That is, for a specified central angle the length of any specified curve equals that central angle expressed in degrees and decimals of a degree divided by the degree of curve expressed in degrees and decimals multiplied by 100; i.e., the length of a 10° 15′ curve for a central angle of 20° 45′ = $\frac{20.75}{10.25} \times 100' = 202.4'$ and is expressed by the formula

TABLE 30. FUNCTIONS OF A ONE-DEGREE CURVE FIGURED ON A BASIS OF $R = 5730'$ AND TABULATED TO TENTHS OF FEET

Use 100′ chords up to 8° Curves
Use 50′ chords up to 16° Curves
Use 25′ chords up to 32° Curves
Use 10′ chords above 32° Curves

Minutes	0°		1°		2°		3°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	0.0	0.0	0.2	50.0	0.9	100.0	2.0	150.1	0
10	0.0	8.3	0.3	58.3	1.0	108.4	2.2	158.4	10
20	0.0	16.7	0.4	66.7	1.2	116.7	2.4	166.8	20
30	0.1	25.0	0.5	75.0	1.4	125.0	2.7	175.1	30
40	0.1	33.3	0.6	83.3	1.6	133.4	2.9	183.4	40
50	0.2	41.7	0.7	91.7	1.8	141.7	3.2	191.7	50
60	0.2	50.0	0.9	100.0	2.0	150.1	3.5	200.1	60

Use 100′ chords up to 8° Curves
Use 50′ chords up to 16° Curves
Use 25′ chords up to 32° Curves
Use 10′ chords above 32° Curves

Minutes	Dec. of Degree	4° Ext.	4° Tan.	5° Ext.	5° Tan.	6° Ext.	6° Tan.	7° Ext.	7° Tan.	Minutes
0	.0000	3.5	200.1	5.5	250.2	7.9	300.3	10.7	350.4	0
1	.0167	3.5	200.9	5.5	251.0	7.9	301.1	10.8	351.3	1
2	.0333	3.6	201.8	5.5	251.8	8.0	302.0	10.8	352.1	2
3	.0500	3.6	202.6	5.6	252.7	8.0	302.8	10.9	352.9	3
4	.0667	3.6	203.4	5.6	253.5	8.0	303.6	10.9	353.8	4
5	.0833	3.6	204.3	5.6	254.3	8.1	304.5	11.0	354.6	5
6	.1000	3.7	205.1	5.7	255.2	8.1	305.3	11.0	355.5	6
7	.1167	3.7	205.9	5.7	256.0	8.2	306.1	11.1	356.3	7
8	.1333	3.7	206.8	5.8	256.8	8.2	307.0	11.1	357.1	8
9	.1500	3.8	207.6	5.8	257.7	8.3	307.8	11.2	358.0	9
10	.1667	3.8	208.4	5.8	258.5	8.3	308.6	11.2	358.8	10
11	.1833	3.8	209.3	5.9	259.3	8.4	309.5	11.3	359.6	11
12	.2000	3.9	210.1	5.9	260.2	8.4	310.3	11.3	360.5	12
13	.2167	3.9	210.9	5.9	261.0	8.4	311.1	11.4	361.3	13
14	.2333	3.9	211.8	6.0	261.9	8.5	312.0	11.4	362.2	14
15	.2500	3.9	212.6	6.0	262.7	8.5	312.8	11.5	363.0	15
16	.2667	4.0	213.4	6.1	263.5	8.6	313.7	11.5	363.8	16
17	.2833	4.0	214.3	6.1	264.4	8.6	314.5	11.6	364.7	17
18	.3000	4.0	215.1	6.1	265.2	8.7	315.3	11.7	365.5	18
19	.3167	4.1	215.9	6.2	266.0	8.7	316.2	11.7	366.3	19
20	.3333	4.1	216.8	6.2	266.9	8.8	317.0	11.8	367.2	20
21	.3500	4.1	217.6	6.2	267.7	8.8	317.8	11.8	368.0	21
22	.3667	4.2	218.4	6.3	268.5	8.9	318.7	11.9	368.8	22
23	.3833	4.2	219.3	6.3	269.4	8.9	319.5	11.9	369.7	23
24	.4000	4.2	220.1	6.4	270.2	9.0	320.3	12.0	370.5	24
25	.4167	4.3	220.9	6.4	271.0	9.0	321.2	12.0	371.4	25
26	.4333	4.3	221.8	6.4	271.9	9.0	322.0	12.1	372.2	26
27	.4500	4.3	222.6	6.5	272.7	9.1	322.8	12.1	373.0	27
28	.4667	4.4	223.5	6.5	273.5	9.1	323.7	12.2	373.9	28
29	.4833	4.4	224.3	6.5	274.4	9.2	324.5	12.2	374.7	29
30	.5000	4.4	225.1	6.6	275.2	9.2	325.4	12.3	375.5	30
31	.5167	4.5	226.0	6.6	276.1	9.3	326.2	12.4	376.4	31
32	.5333	4.5	226.8	6.7	276.9	9.3	327.0	12.4	377.2	32
33	.5500	4.5	227.6	6.7	277.7	9.4	327.9	12.5	378.1	33
34	.5667	4.6	228.5	6.8	278.6	9.4	328.7	12.5	378.9	34
35	.5833	4.6	229.3	6.8	279.4	9.5	329.5	12.6	379.7	35
36	.6000	4.6	230.1	6.8	280.2	9.5	330.4	12.6	380.6	36
37	.6167	4.7	231.0	6.9	281.1	9.6	331.2	12.7	381.4	37
38	.6333	4.7	231.8	6.9	281.9	9.6	332.0	12.7	382.2	38
39	.6500	4.7	232.6	7.0	282.7	9.7	332.9	12.8	383.1	39
40	.6667	4.8	233.5	7.0	283.6	9.7	333.7	12.9	383.9	40
41	.6833	4.8	234.3	7.1	284.4	9.8	334.6	12.9	384.7	41
42	.7000	4.8	235.1	7.1	285.2	9.8	335.4	13.0	385.6	42
43	.7167	4.9	236.0	7.1	286.1	9.9	336.2	13.0	386.4	43
44	.7333	4.9	236.8	7.2	286.9	9.9	337.1	13.1	387.3	44
45	.7500	4.9	237.6	7.2	287.7	10.0	337.9	13.1	388.1	45
46	.7667	5.0	238.5	7.3	288.6	10.0	338.7	13.2	388.9	46
47	.7833	5.0	239.3	7.3	289.4	10.1	339.6	13.2	389.8	47
48	.8000	5.0	240.1	7.3	290.3	10.1	340.4	13.3	390.6	48
49	.8167	5.1	241.0	7.4	291.1	10.2	341.2	13.4	391.4	49
50	.8333	5.1	241.8	7.4	291.9	10.2	342.1	13.4	392.3	50
51	.8500	5.1	242.6	7.5	292.8	10.3	342.9	13.5	393.1	51
52	.8667	5.2	243.5	7.5	293.6	10.3	343.7	13.5	394.0	52
53	.8833	5.2	244.3	7.5	294.4	10.4	344.6	13.6	394.8	53
54	.9000	5.2	245.2	7.6	295.3	10.4	345.4	13.7	395.6	54
55	.9167	5.3	246.0	7.6	296.1	10.5	346.3	13.7	396.5	55
56	.9333	5.3	246.8	7.7	296.9	10.5	347.1	13.8	397.3	56
57	.9500	5.3	247.7	7.7	297.8	10.6	347.9	13.8	398.1	57
58	.9667	5.4	248.5	7.8	298.6	10.6	348.8	13.9	399.0	58
59	.9833	5.4	249.3	7.8	299.4	10.7	349.6	13.9	399.8	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	8°		9°		10°		11°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	14.0	400.7	17.7	450.9	21.9	501.3	26.5	551.7	0
1	.0167	14.0	401.5	17.8	451.8	21.9	502.2	26.6	552.6	1
2	.0333	14.1	402.4	17.8	452.6	22.0	503.0	26.7	553.4	2
3	.0500	14.2	403.2	17.9	453.4	22.1	503.8	26.7	554.3	3
4	.0667	14.2	404.0	18.0	454.3	22.2	504.7	26.8	555.1	4
5	.0833	14.3	404.8	18.0	455.1	22.3	505.5	26.9	555.9	5
6	.1000	14.3	405.7	18.1	456.0	22.3	506.4	27.0	556.8	6
7	.1167	14.4	406.5	18.2	456.8	22.4	507.2	27.1	557.6	7
8	.1333	14.5	407.4	18.3	457.7	22.5	508.0	27.2	558.5	8
9	.1500	14.5	408.2	18.3	458.5	22.6	508.9	27.2	559.3	9
10	.1667	14.6	409.0	18.4	459.3	22.6	509.7	27.3	560.1	10
11	.1833	14.6	409.9	18.4	460.2	22.7	510.6	27.4	561.0	11
12	.2000	14.7	410.7	18.5	461.0	22.8	511.4	27.5	561.8	12
13	.2167	14.8	411.5	18.6	461.8	22.9	512.2	27.6	562.7	13
14	.2333	14.8	412.4	18.7	462.7	22.9	513.1	27.7	563.5	14
15	.2500	14.9	413.2	18.7	463.5	23.0	513.9	27.7	564.3	15
16	.2667	14.9	414.1	18.8	464.4	23.1	514.8	27.8	565.2	16
17	.2833	15.0	414.9	18.9	465.2	23.2	515.6	27.9	566.0	17
18	.3000	15.1	415.7	18.9	466.0	23.2	516.4	28.0	566.9	18
19	.3167	15.1	416.6	19.0	466.9	23.3	517.3	28.1	567.7	19
20	.3333	15.2	417.4	19.1	467.7	23.4	518.1	28.1	568.5	20
21	.3500	15.2	418.2	19.1	468.5	23.5	519.0	28.2	569.4	21
22	.3667	15.3	419.1	19.2	469.4	23.5	519.8	28.3	570.2	22
23	.3833	15.4	419.9	19.3	470.2	23.6	520.6	28.4	571.1	23
24	.4000	15.4	420.8	19.3	471.1	23.7	521.5	28.5	571.9	24
25	.4167	15.5	421.6	19.4	471.9	23.8	522.3	28.6	572.8	25
26	.4333	15.6	422.4	19.5	472.8	23.8	523.2	28.6	573.6	26
27	.4500	15.6	423.3	19.5	473.6	23.9	524.0	28.7	574.4	27
28	.4667	15.7	424.1	19.6	474.4	24.0	524.9	28.8	575.3	28
29	.4833	15.7	424.9	19.7	475.3	24.1	525.7	28.9	576.1	29
30	.5000	15.8	425.8	19.8	476.1	24.1	526.5	29.0	577.0	30
31	.5167	15.9	426.6	19.8	476.9	24.2	527.4	29.1	577.8	31
32	.5333	15.9	427.5	19.9	477.8	24.3	528.2	29.1	578.6	32
33	.5500	16.0	428.3	20.0	478.6	24.4	529.0	29.2	579.5	33
34	.5667	16.0	429.1	20.0	479.5	24.5	529.9	29.3	580.3	34
35	.5833	16.1	430.0	20.1	480.3	24.5	530.7	29.4	581.2	35
36	.6000	16.2	430.8	20.2	481.1	24.6	531.6	29.5	582.0	36
37	.6167	16.2	431.7	20.2	482.0	24.7	532.4	29.6	582.8	37
38	.6333	16.3	432.5	20.3	482.8	24.8	533.3	29.7	583.7	38
39	.6500	16.4	433.3	20.4	483.6	24.8	534.1	29.7	584.5	39
40	.6667	16.4	434.2	20.5	484.5	24.9	534.9	29.8	585.4	40
41	.6833	16.5	435.0	20.5	485.3	25.0	535.8	29.9	586.2	41
42	.7000	16.6	435.9	20.6	486.2	25.1	536.6	30.0	587.1	42
43	.7167	16.6	436.7	20.7	487.0	25.1	537.5	30.1	587.9	43
44	.7333	16.7	437.5	20.7	487.9	25.2	538.3	30.2	588.7	44
45	.7500	16.7	438.4	20.8	488.7	25.3	539.1	30.3	589.6	45
46	.7667	16.8	439.2	20.9	489.6	25.4	540.0	30.3	590.4	46
47	.7833	16.9	440.0	21.0	490.4	25.5	540.8	30.4	591.3	47
48	.8000	16.9	440.9	21.0	491.2	25.5	541.7	30.5	592.1	48
49	.8167	17.0	441.7	21.1	492.0	25.6	542.5	30.6	592.9	49
50	.8333	17.1	442.5	21.2	492.9	25.7	543.3	30.7	593.8	50
51	.8500	17.1	443.4	21.2	493.7	25.8	544.2	30.8	594.6	51
52	.8667	17.2	444.2	21.3	494.6	25.9	545.0	30.9	595.5	52
53	.8833	17.3	445.1	21.4	495.4	25.9	545.9	31.0	596.3	53
54	.9000	17.3	445.9	21.5	496.3	26.0	546.7	31.0	597.2	54
55	.9167	17.4	446.7	21.5	497.1	26.1	547.5	31.1	598.0	55
56	.9333	17.5	447.6	21.6	498.0	26.2	548.4	31.2	598.8	56
57	.9500	17.5	448.4	21.7	498.8	26.3	549.2	31.3	599.7	57
58	.9667	17.6	449.3	21.8	499.6	26.3	550.1	31.4	600.5	58
59	.9833	17.6	450.1	21.8	500.4	26.4	550.9	31.5	601.4	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	12° Ext.	12° Tan.	13° Ext.	13° Tan.	14° Ext.	14° Tan.	15° Ext.	15° Tan.	Minutes
0	.0000	31.6	602.2	37.1	652.9	43.0	703.5	49.4	754.4	0
1	.0167	31.7	603.1	37.2	653.7	43.1	704.4	49.6	755.2	1
2	.0333	31.7	603.9	37.3	654.6	43.2	705.2	49.7	756.1	2
3	.0500	31.8	604.7	37.4	655.4	43.3	706.1	49.8	756.9	3
4	.0667	31.9	605.6	37.5	656.3	43.4	706.9	49.9	757.7	4
5	.0833	32.0	606.4	37.6	657.1	43.5	707.8	50.0	758.6	5
6	.1000	32.1	607.3	37.7	657.9	43.7	708.6	50.1	759.4	6
7	.1167	32.2	608.1	37.7	658.8	43.8	709.5	50.2	760.3	7
8	.1333	32.3	609.0	37.8	659.6	43.9	710.3	50.3	761.1	8
9	.1500	32.4	609.8	37.9	660.5	44.0	711.2	50.5	762.0	9
10	.1667	32.5	610.7	38.0	661.3	44.1	712.0	50.6	762.8	10
11	.1833	32.5	611.5	38.1	662.2	44.2	712.9	50.7	763.7	11
12	.2000	32.6	612.4	38.2	663.0	44.3	713.7	50.8	764.5	12
13	.2167	32.7	613.2	38.3	663.8	44.4	714.6	50.9	765.4	13
14	.2333	32.8	614.0	38.4	664.7	44.5	715.4	51.0	766.2	14
15	.2500	32.9	614.9	38.5	665.5	44.6	716.3	51.1	767.1	15
16	.2667	33.0	615.7	38.6	666.4	44.7	717.1	51.2	767.9	16
17	.2833	33.1	616.6	38.7	667.2	44.8	718.0	51.3	768.8	17
18	.3000	33.2	617.4	38.8	668.1	44.9	718.8	51.5	769.6	18
19	.3167	33.3	618.3	38.9	668.9	45.0	719.6	51.6	770.5	19
20	.3333	33.4	619.1	39.0	669.8	45.1	720.5	51.7	771.3	20
21	.3500	33.4	619.9	39.1	670.6	45.2	721.3	51.8	772.2	21
22	.3667	33.5	620.8	39.2	671.4	45.3	722.2	51.9	773.0	22
23	.3833	33.6	621.6	39.3	672.3	45.4	723.1	52.0	773.9	23
24	.4000	33.7	622.5	39.4	673.1	45.5	723.9	52.1	774.7	24
25	.4167	33.8	623.3	39.5	674.0	45.6	724.7	52 3	775.6	25
26	.4333	33.9	624.2	39.6	674.8	45.8	725.6	52.4	776.4	26
27	.4500	34.0	625.0	39.7	675.7	45.9	726.5	52.5	777.3	27
28	.4667	34.1	625.9	39.8	676.5	46.0	727.3	52.6	778.1	28
29	.4833	34.2	626.7	39.9	677.4	46.1	728.1	52.7	778.9	29
30	.5000	34.3	627.6	40.0	678.2	46.2	729.0	52.8	779.8	30
31	.5167	34.4	628.4	40.1	679.0	46.3	729.8	52.9	780.6	31
32	.5333	34.5	629.2	40.2	679.9	46.4	730.7	53.1	781.5	32
33	.5500	34.5	630.1	40.3	680.7	46.5	731.5	53.2	782.3	33
34	.5667	34.6	630.9	40.4	681.6	46.6	732.4	53.3	783.2	34
35	.5833	34.7	631.8	40.5	682.4	46.7	733.2	53.4	784.0	35
36	.6000	34.8	632.6	40.6	683.3	46.8	734.0	53.5	784.9	36
37	.6167	34.9	633.5	40.7	684.1	46.9	734.9	53.6	785.7	37
38	.6333	35.0	634.3	40.8	685.0	47.0	735.7	53.7	786.6	38
39	.6500	35.1	635.1	40.9	685.8	47.2	736.6	53.9	787.4	39
40	.6667	35.2	636.0	41.0	686.6	47.3	737.4	54.0	788.3	40
41	.6833	35.3	636.8	41.1	687.5	47.4	738.3	54.1	789.1	41
42	.7000	35.4	637.7	41.2	688.3	47.5	739.1	54.2	790.0	42
43	.7167	35.5	638.5	41.3	689.2	47.6	740.0	54.3	790.8	43
44	.7333	35.6	639.4	41.4	690.0	47.7	740.8	54.4	791.7	44
45	.7500	35.7	640.2	41.5	690.9	47.8	741.7	54.6	792.5	45
46	.7667	35.8	641.1	41.6	691.7	47.9	742.5	54.7	793.4	46
47	.7833	35.8	641.9	41.7	692.5	48.0	743.4	54.8	794.2	47
48	.8000	35.9	642.7	41.8	693.4	48.1	744.2	54.9	795.1	48
49	.8167	36.0	643.6	41.9	694.2	48.2	745.1	55.0	795.9	49
50	.8333	36.1	644.4	42.0	695.1	48.3	745.9	55.1	796.8	50
51	.8500	36.2	645.3	42.1	695.9	48.5	746.7	55.3	797.6	51
52	.8667	36.3	646.1	42.2	696.8	48.6	747.6	55.4	798.5	52
53	.8833	36.4	647.0	42.3	697.6	48.7	748.4	55.5	799.3	53
54	.9000	36.5	647.8	42.4	698.5	48.8	749.3	55.6	800.2	54
55	.9167	36.6	648.6	42.5	699.3	48.9	750.1	55.7	801.0	55
56	.9333	36.7	649.5	42.6	700.1	49.0	751.0	55.8	801.9	56
57	.9500	36.8	650.3	42.7	701.0	49.1	751.8	56.0	802.7	57
58	.9667	36.9	651.2	42.8	701.8	49.2	752.7	56.1	803.6	58
59	.9833	37.0	652.0	42.9	702.7	49.3	753.5	56.2	804.4	59

Use 100′ Chords up to 8° Curves · Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	16°		17°		18°		19°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	56.3	805.3	63.6	856.4	71.4	907.5	79.7	958.9	0
1	.0167	56.4	806.2	63.8	857.2	71.6	908.4	79.8	959.7	1
2	.0333	56.5	807.0	63.9	858.1	71.7	909.2	79.9	960.6	2
3	.0500	56.7	807.8	64.0	858.9	71.8	910.1	80.1	961.4	3
4	.0667	56.8	808.6	64.2	859.8	72.0	910.9	80.2	962.3	4
5	.0833	56.9	809.5	64.3	860.6	72.1	911.8	80.4	963.2	5
6	.1000	57.0	810.4	64.4	861.5	72.2	912.7	80.5	964.0	6
7	.1167	57.1	811.2	64.5	862.3	72.4	913.5	80.7	964.9	7
8	.1333	57.3	812.1	64.7	863.2	72.5	914.4	80.8	965.7	8
9	.1500	57.4	812.9	64.8	864.0	72.6	915.2	80.9	966.6	9
10	.1667	57.5	813.8	64.9	864.9	72.8	916.1	81.1	967.4	10
11	.1833	57.6	814.6	65.0	865.7	72.9	916.9	81.2	968.3	11
12	.2000	57.7	815.5	65.2	866.6	73.0	917.8	81.4	969.2	12
13	.2167	57.9	816.3	65.3	867.4	73.2	918.6	81.5	970.0	13
14	.2333	58.0	817.2	65.4	868.3	73.3	919.5	81.7	970.9	14
15	.2500	58.1	818.0	65.6	869.1	73.4	920.3	81.8	971.7	15
16	.2667	58.2	818.9	65.7	870.0	73.6	921.2	81.9	972.6	16
17	.2833	58.3	819.7	65.8	870.8	73.7	922.0	82.1	973.4	17
18	.3000	58.5	820.6	65.9	871.7	73.9	922.9	82.2	974.3	18
19	.3167	58.6	821.4	66.1	872.5	74.0	923.8	82.4	975.1	19
20	.3333	58.7	822.3	66.2	873.4	74.1	924.6	82.5	976.0	20
21	.3500	58.8	823.1	66.3	874.2	74.3	925.5	82.7	976.9	21
22	.3667	58.9	824.0	66.4	875.1	74.4	926.3	82.8	977.7	22
23	.3833	59.1	824.8	66.6	875.9	74.5	927.2	82.9	978.6	23
24	.4000	59.2	825.7	66.7	876.8	74.7	928.1	83.1	979.4	24
25	.4167	59.3	826.5	66.8	877.6	74.8	928.9	83.2	980.3	25
26	.4333	59.4	827.4	67.0	878.5	74.9	929.8	83.4	981.2	26
27	.4500	59.6	828.2	67.1	879.3	75.1	930.6	83.5	982.0	27
28	.4667	59.7	829.1	67.2	880.2	75.2	931.5	83.7	982.9	28
29	.4833	59.8	829.9	67.3	881.0	75.4	932.3	83.8	983.7	29
30	.5000	59.9	830.8	67.5	881.9	75.5	933.2	84.0	984.6	30
31	.5167	60.0	831.6	67.6	882.7	75.6	934.0	84.1	985.4	31
32	.5333	60.2	832.5	67.7	883.6	75.8	934.9	84.3	986.3	32
33	.5500	60.3	833.3	67.9	884.5	75.9	935.7	84.4	987.2	33
34	.5667	60.4	834.2	68.0	885.3	76.1	936.6	84.6	988.0	34
35	.5833	60.5	835.1	68.1	886.2	76.2	937.5	84.7	988.9	35
36	.6000	60.7	835.9	68.2	887.0	76.3	938.3	84.8	989.7	36
37	.6167	60.8	836.8	68.4	887.9	76.5	939.2	85.0	990.6	37
38	.6333	60.9	837.6	68.5	888.7	76.6	940.0	85.1	991.5	38
39	.6500	61.0	838.5	68.6	889.6	76.7	940.9	85.3	992.3	39
40	.6667	61.1	839.3	68.8	890.4	76.9	941.7	85.4	993.2	40
41	.6833	61.3	840.2	68.9	891.3	77.0	942.6	85.6	994.0	41
42	.7000	61.4	841.0	69.0	892.2	77.1	943.5	85.7	994.9	42
43	.7167	61.5	841.9	69.2	893.0	77.3	944.3	85.9	995.8	43
44	.7333	61.6	842.7	69.3	893.9	77.4	945.2	86.0	996.6	44
45	.7500	61.8	843.6	69.4	894.7	77.6	946.0	86.2	997.5	45
46	.7667	61.9	844.4	69.6	895.6	77.7	946.9	86.3	998.3	46
47	.7833	62.0	845.3	69.7	896.4	77.8	947.7	86.5	999.2	47
48	.8000	62.1	846.1	69.8	897.3	78.0	948.6	86.6	1000.0	48
49	.8167	62.3	847.0	70.0	898.1	78.1	949.4	86.8	1000.9	49
50	.8333	62.4	847.8	70.1	899.0	78.3	950.3	86.9	1001.8	50
51	.8500	62.5	848.7	70.2	899.8	78.4	951.1	87.1	1002.6	51
52	.8667	62.6	849.5	70.4	900.7	78.5	952.0	87.2	1003.5	52
53	.8833	62.8	850.4	70.5	901.5	78.7	952.9	87.4	1004.3	53
54	.9000	62.9	851.2	70.6	902.4	78.8	953.7	87.5	1005.2	54
55	.9167	63.0	852.1	70.8	903.3	79.0	954.6	87.7	1006.0	55
56	.9333	63.1	852.9	70.9	904.1	79.1	955.4	87.8	1006.9	56
57	.9500	63.3	853.8	71.0	905.0	79.2	956.3	88.0	1007.7	57
58	.9667	63.4	854.7	71.2	905.8	79.4	957.2	88.1	1008.6	58
59	.9833	63.5	855.5	71.3	906.7	79.5	958.0	88.2	1009.5	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32°
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32°

Minutes	Dec. of Degree	20°		21°		22°		23°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	88.4	1010.4	97.6	1062.0	107.2	1113.8	117.4	1165.8	0
1	.0167	88.5	1011.2	97.7	1062.8	107.4	1114.6	117.6	1166.6	1
2	.0333	88.7	1012.1	97.9	1063.7	107.6	1115.5	117.7	1167.5	2
3	.0500	88.8	1012.9	98.1	1064.5	107.7	1116.4	117.9	1168.3	3
4	.0667	89.0	1013.8	98.2	1065.4	107.9	1117.3	118.1	1169.2	4
5	.0833	89.1	1014.6	98.4	1066.3	108.0	1118.1	118.3	1170.1	5
6	.1000	89.3	1015.5	98.5	1067.2	108.2	1119.0	118.4	1171.0	6
7	.1167	89.4	1016.3	98.7	1068.0	108.4	1119.8	118.6	1171.8	7
8	.1333	89.6	1017.2	98.8	1068.9	108.6	1120.7	118.8	1172.7	8
9	.1500	89.7	1018.1	99.0	1069.7	108.7	1121.5	118.9	1173.5	9
10	.1667	89.9	1019.0	99.2	1070.6	108.9	1122.4	119.1	1174.4	10
11	.1833	90.0	1019.8	99.3	1071.5	109.0	1123.3	119.3	1175.3	11
12	.2000	90.2	1020.7	99.5	1072.4	109.2	1124.2	119.5	1176.2	12
13	.2167	90.3	1021.5	99.6	1073.2	109.4	1125.0	119.7	1177.0	13
14	.2333	90.5	1022.4	99.8	1074.1	109.6	1125.9	119.8	1177.9	14
15	.2500	90.6	1023.2	99.9	1074.9	109.7	1126.7	120.0	1178.8	15
16	.2667	90.8	1024.1	100.1	1075.8	109.9	1127.6	120.2	1179.7	16
17	.2833	90.9	1024.9	100.2	1076.6	110.0	1128.5	120.4	1180.5	17
18	.3000	91.1	1025.8	100.4	1077.5	110.2	1129.4	120.5	1181.4	18
19	.3167	91.2	1026.7	100.5	1078.4	110.4	1130.2	120.7	1182.2	19
20	.3333	91.4	1027.6	100.7	1079.3	110.6	1131.1	120.9	1183.1	20
21	.3500	91.6	1028.4	100.9	1080.1	110.7	1131.9	121.0	1184.0	21
22	.3667	91.7	1029.3	101.1	1081.0	110.9	1132.8	121.2	1184.9	22
23	.3833	91.9	1030.1	101.2	1081.8	111.0	1133.7	121.4	1185.7	23
24	.4000	92.0	1031.0	101.4	1082.7	111.2	1134.6	121.6	1186.6	24
25	.4167	92.2	1031.8	101.5	1083.5	111.4	1135.4	121.7	1187.5	25
26	.4333	92.3	1032.7	101.7	1084.4	111.6	1136.3	121.9	1188.4	26
27	.4500	92.5	1033.5	101.8	1085.3	111.7	1137.1	122.1	1189.2	27
28	.4667	92.6	1034.4	102.0	1086.2	111.9	1138.0	122.3	1190.1	28
29	.4833	92.8	1035.2	102.1	1087.0	112.1	1138.8	122.4	1190.9	29
30	.5000	92.9	1036.1	102.3	1087.9	112.3	1139.7	122.6	1191.8	30
31	.5167	93.1	1037.0	102.5	1088.7	112.4	1140.6	122.8	1192.7	31
32	.5333	93.2	1037.9	102.7	1089.6	112.6	1141.5	123.0	1193.6	32
33	.5500	93.4	1038.7	102.8	1090.4	112.7	1142.3	123.2	1194.4	33
34	.5667	93.5	1039.6	103.0	1091.3	112.9	1143.2	123.3	1195.3	34
35	.5833	93.7	1040.4	103.1	1092.2	113.1	1144.0	123.5	1196.2	35
36	.6000	93.9	1041.3	103.3	1093.1	113.3	1144.9	123.7	1197.1	36
37	.6167	94.0	1042.1	103.4	1093.9	113.4	1145.8	123.9	1197.9	37
38	.6333	94.2	1043.0	103.6	1094.8	113.6	1146.7	124.1	1198.8	38
39	.6500	94.3	1043.9	103.8	1095.6	113.7	1147.5	124.3	1199.6	39
40	.6667	94.5	1044.8	104.0	1096.5	113.9	1148.4	124.4	1200.5	40
41	.6833	94.6	1045.6	104.1	1097.4	114.1	1149.2	124.6	1201.4	41
42	.7000	94.8	1046.5	104.3	1098.3	114.3	1150.1	124.8	1202.3	42
43	.7167	94.9	1047.3	104.4	1099.1	114.4	1151.0	124.9	1203.1	43
44	.7333	95.1	1048.2	104.6	1100.0	114.6	1151.9	125.1	1204.0	44
45	.7500	95.2	1049.0	104.7	1100.8	114.8	1152.7	125.3	1204.9	45
46	.7667	95.4	1049.9	104.9	1101.7	115.0	1153.6	125.5	1205.8	46
47	.7833	95.6	1050.8	105.1	1102.5	115.2	1154.5	125.7	1206.7	47
48	.8000	95.7	1051.7	105.3	1103.4	115.3	1155.4	125.8	1207.5	48
49	.8167	95.9	1052.5	105.4	1104.3	115.5	1156.2	126.0	1208.3	49
50	.8333	96.0	1053.4	105.6	1105.2	115.7	1157.1	126.2	1209.2	50
51	.8500	96.2	1054.2	105.7	1106.0	115.8	1157.9	126.4	1210.1	51
52	.8667	96.3	1055.1	105.9	1106.9	116.0	1158.8	126.6	1211.0	52
53	.8833	96.5	1055.9	106.1	1107.8	116.1	1159.7	126.7	1211.8	53
54	.9000	96.7	1056.8	106.3	1108.6	116.3	1160.6	126.9	1212.7	54
55	.9167	96.8	1057.7	106.4	1109.4	116.5	1161.4	127.1	1213.6	55
56	.9333	97.0	1058.6	106.6	1110.3	116.7	1162.3	127.3	1214.5	56
57	.9500	97.1	1059.4	106.7	1111.2	116.8	1163.1	127.5	1215.3	57
58	.9667	97.3	1060.3	106.9	1112.1	117.0	1164.0	127.6	1216.2	58
59	.9833	97.4	1061.1	107.0	1112.9	117.2	1164.9	127.8	1217.1	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	24°		25°		26°		27°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	128.0	1218.0	139.1	1270.3	150.7	1322.9	162.8	1375.6	0
1	.0167	128.2	1218.8	139.3	1271.1	150.9	1323.7	163.0	1376.5	1
2	.0333	128.4	1219.7	139.5	1272.0	151.1	1324.6	163.2	1377.4	2
3	.0500	128.5	1220.5	139.7	1272.9	151.3	1325.5	163.5	1378.3	3
4	.0667	128.7	1221.4	139.9	1273.8	151.5	1326.4	163.7	1379.2	4
5	.0833	128.9	1222.3	140.1	1274.6	151.7	1327.3	163.9	1380.0	5
6	.1000	129.1	1223.2	140.3	1275.5	151.9	1328.1	164.1	1380.9	6
7	.1167	129.3	1224.0	140.4	1276.4	152.1	1329.0	164.3	1381.8	7
8	.1333	129.5	1224.9	140.6	1277.3	152.3	1329.9	164.5	1382.7	8
9	.1500	129.7	1225.8	140.8	1278.2	152.5	1330.7	164.7	1383.6	9
10	.1667	129.8	1226.7	141.0	1279.1	152.7	1331.6	164.9	1384.5	10
11	.1833	130.0	1227.5	141.2	1279.9	152.9	1332.5	165.1	1385.3	11
12	.2000	130.2	1228.4	141.4	1280.8	153.1	1333.4	165.3	1386.2	12
13	.2167	130.4	1229.3	141.6	1281.6	153.3	1334.3	165.5	1387.1	13
14	.2333	130.6	1230.2	141.8	1282.5	153.5	1335.2	165.7	1388.0	14
15	.2500	130.7	1231.0	142.0	1283.4	153.7	1336.0	165.9	1388.9	15
16	.2667	130.9	1231.9	142.2	1284.3	153.9	1336.9	166.1	1389.8	16
17	.2833	131.1	1232.7	142.3	1285.2	154.1	1337.8	166.3	1390.6	17
18	.3000	131.3	1233.6	142.5	1286.1	154.3	1338.7	166.5	1391.5	18
19	.3167	131.5	1234.5	142.7	1286.9	154.5	1339.5	166.7	1392.4	19
20	.3333	131.7	1235.4	142.9	1287.8	154.7	1340.4	167.0	1393.3	20
21	.3500	131.9	1236.2	143.1	1288.7	154.9	1341.3	167.2	1394.1	21
22	.3667	132.0	1237.1	143.3	1289.6	155.1	1342.2	167.4	1395.0	22
23	.3833	132.2	1238.0	143.5	1290.4	155.3	1343.0	167.6	1395.9	23
24	.4000	132.4	1238.9	143.7	1291.3	155.5	1343.9	167.8	1396.8	24
25	.4167	132.6	1239.7	143.9	1292.2	155.7	1344.8	168.0	1397.7	25
26	.4333	132.8	1240.6	144.1	1293.1	155.9	1345.7	168.2	1398.6	26
27	.4500	133.0	1241.5	144.3	1293.9	156.1	1346.5	168.4	1399.4	27
28	.4667	133.1	1242.4	144.5	1294.8	156.3	1347.4	168.6	1400.3	28
29	.4833	133.3	1243.2	144.7	1295.7	156.5	1348.3	168.9	1401.2	29
30	.5000	133.5	1244.1	144.9	1296.6	156.7	1349.2	169.1	1402.1	30
31	.5167	133.7	1244.9	145.1	1297.4	156.9	1350.1	169.3	1403.0	31
32	.5333	133.9	1245.8	145.3	1298.3	157.1	1351.0	169.5	1403.9	32
33	.5500	134.0	1246.7	145.5	1299.2	157.3	1351.8	169.7	1404.7	33
34	.5667	134.2	1247.6	145.6	1300.1	157.5	1352.7	169.9	1405.6	34
35	.5833	134.4	1248.4	145.8	1300.9	157.7	1353.6	170.1	1406.5	35
36	.6000	134.6	1249.3	146.0	1301.8	157.9	1354.5	170.3	1407.4	36
37	.6167	134.9	1250.2	146.2	1302.7	158.1	1355.3	170.5	1408.3	37
38	.6333	135.0	1251.1	146.4	1303.6	158.3	1356.2	170.8	1409.2	38
39	.6500	135.2	1251.9	146.6	1304.4	158.5	1357.1	171.0	1410.0	39
40	.6667	135.4	1252.8	146.8	1305.3	158.7	1358.0	171.2	1410.9	40
41	.6833	135.6	1253.7	147.0	1306.2	158.9	1358.9	171.4	1411.8	41
42	.7000	135.7	1254.6	147.2	1307.1	159.1	1359.8	171.6	1412.7	42
43	.7167	135.9	1255.4	147.4	1307.9	159.3	1360.6	171.8	1413.6	43
44	.7333	136.1	1256.3	147.6	1308.8	159.5	1361.5	172.0	1414.5	44
45	.7500	136.3	1257.2	147.8	1309.7	159.7	1362.4	172.2	1415.4	45
46	.7667	136.5	1258.1	148.0	1310.6	160.0	1363.3	172.5	1416.3	46
47	.7833	136.7	1258.9	148.2	1311.5	160.2	1364.2	172.7	1417.1	47
48	.8000	136.9	1259.8	148.4	1312.4	160.4	1365.1	172.9	1418.0	48
49	.8167	137.1	1260.7	148.6	1313.2	160.6	1365.9	173.1	1418.9	49
50	.8333	137.2	1261.5	148.8	1314.1	160.8	1366.8	173.3	1419.8	50
51	.8500	137.4	1262.4	149.0	1315.0	161.0	1367.7	173.5	1420.7	51
52	.8667	137.6	1263.3	149.2	1315.9	161.2	1368.6	173.7	1421.6	52
53	.8833	137.8	1264.1	149.4	1316.7	161.4	1369.5	173.9	1422.4	53
54	.9000	138.0	1265.0	149.5	1317.6	161.6	1370.4	174.1	1423.3	54
55	.9167	138.2	1265.9	149.7	1318.5	161.8	1371.2	174.4	1424.2	55
56	.9333	138.4	1266.8	149.9	1319.4	162.0	1372.1	174.6	1425.1	56
57	.9500	138.6	1267.6	150.1	1320.3	162.2	1373.0	174.8	1426.0	57
58	.9667	138.7	1268.5	150.3	1321.1	162.4	1373.9	175.0	1426.9	58
59	.9833	138.9	1269.4	150.5	1322.0	162.6	1374.7	175.2	1427.7	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	28°		29°		30°		31°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	175.4	1428.6	188.5	1481.9	202.1	1535.3	216.3	1589.0	0
1	.0167	175.6	1429.5	188.7	1482.8	202.3	1536.2	216.5	1589.9	1
2	.0333	175.8	1430.4	189.0	1483.7	202.6	1537.1	216.8	1590.8	2
3	.0500	176.0	1431.3	189.2	1484.5	202.8	1538.0	217.0	1591.7	3
4	.0667	176.3	1432.2	189.4	1485.4	203.1	1538.9	217.2	1592.6	4
5	.0833	176.5	1433.1	189.6	1486.3	203.3	1539.8	217.4	1593.5	5
6	.1000	176.7	1434.0	189.9	1487.2	203.5	1540.7	217.7	1594.4	6
7	.1167	176.9	1434.8	190.1	1488.1	203.7	1541.6	217.9	1595.3	7
8	.1333	177.1	1435.7	190.3	1489.0	204.0	1542.5	218.2	1596.2	8
9	.1500	177.3	1436.6	190.5	1489.9	204.2	1543.4	218.4	1597.1	9
10	.1667	177.6	1437.5	190.8	1490.8	204.5	1544.3	218.7	1598.0	10
11	.1833	177.8	1438.4	191.0	1491.7	204.7	1545.2	218.9	1598.9	11
12	.2000	178.0	1439.3	191.2	1492.6	204.9	1546.0	219.2	1599.8	12
13	.2167	178.2	1440.2	191.5	1493.4	205.1	1546.9	219.4	1600.7	13
14	.2333	178.4	1441.1	191.7	1494.3	205.4	1547.8	219.6	1601.6	14
15	.2500	178.6	1441.9	191.9	1495.2	205.6	1548.7	219.8	1602.5	15
16	.2667	178.9	1442.8	192.1	1496.1	205.9	1549.6	220.1	1603.4	16
17	.2833	179.1	1443.7	192.3	1497.0	206.1	1550.5	220.3	1604.3	17
18	.3000	179.3	1444.6	192.5	1497.9	206.3	1551.4	220.6	1605.2	18
19	.3167	179.5	1445.5	192.7	1498.8	206.5	1552.3	220.8	1606.1	19
20	.3333	179.7	1446.4	193.0	1499.7	206.8	1553.2	221.1	1607.0	20
21	.3500	179.9	1447.3	193.2	1500.6	207.0	1554.1	221.3	1607.9	21
22	.3667	180.2	1448.2	193.5	1501.5	207.3	1555.0	221.6	1608.8	22
23	.3833	180.4	1449.0	193.7	1502.3	207.5	1555.9	221.8	1609.7	23
24	.4000	180.6	1449.9	193.9	1503.2	207.7	1556.8	222.1	1610.6	24
25	.4167	180.8	1450.8	194.1	1504.1	207.9	1557.7	222.3	1611.5	25
26	.4333	181.0	1451.7	194.4	1505.0	208.2	1558.6	222.6	1612.4	26
27	.4500	181.2	1452.6	194.6	1505.9	208.4	1559.5	222.8	1613.3	27
28	.4667	181.5	1453.5	194.8	1506.8	208.7	1560.4	223.0	1614.2	28
29	.4833	181.7	1454.3	195.0	1507.7	208.9	1561.3	223.2	1615.1	29
30	.5000	181.9	1455.2	195.3	1508.6	209.1	1562.2	223.5	1616.0	30
31	.5167	182.1	1456.1	195.5	1509.5	209.3	1563.1	223.7	1616.9	31
32	.5333	182.3	1457.0	195.7	1510.4	209.6	1564.0	224.0	1617.8	32
33	.5500	182.5	1457.9	195.9	1511.2	209.8	1564.9	224.2	1618.7	33
34	.5667	182.8	1458.8	196.2	1512.1	210.1	1565.7	224.5	1619.6	34
35	.5833	183.0	1459.7	196.4	1513.0	210.3	1566.6	224.7	1620.5	35
36	.6000	183.2	1460.6	196.7	1513.9	210.5	1567.5	225.0	1621.4	36
37	.6167	183.4	1461.4	196.9	1514.8	210.7	1568.4	225.2	1622.3	37
38	.6333	183.6	1462.3	197.1	1515.7	211.0	1569.3	225.5	1623.2	38
39	.6500	183.8	1463.2	197.3	1516.6	211.2	1570.2	225.7	1624.1	39
40	.6667	184.1	1464.1	197.6	1517.5	211.5	1571.1	226.0	1625.0	40
41	.6833	184.3	1465.0	197.8	1518.4	211.7	1572.0	226.2	1625.9	41
42	.7000	184.5	1465.9	198.0	1519.3	212.0	1572.9	226.5	1626.8	42
43	.7167	184.7	1466.8	198.2	1520.1	212.2	1573.8	226.7	1627.7	43
44	.7333	185.0	1467.7	198.5	1521.0	212.4	1574.7	227.0	1628.6	44
45	.7500	185.2	1468.6	198.7	1521.9	212.6	1575.6	227.2	1629.5	45
46	.7667	185.4	1469.5	198.9	1522.8	212.9	1576.5	227.5	1630.5	46
47	.7833	185.6	1470.3	199.1	1523.7	213.1	1577.4	227.7	1631.4	47
48	.8000	185.9	1471.2	199.4	1524.6	213.4	1578.3	228.0	1632.3	48
49	.8167	186.1	1472.1	199.6	1525.5	213.6	1579.2	228.2	1633.2	49
50	.8333	186.3	1473.0	199.8	1526.4	213.9	1580.1	228.4	1634.1	50
51	.8500	186.5	1473.9	200.0	1527.3	214.1	1581.0	228.6	1635.0	51
52	.8667	186.8	1474.8	200.3	1528.2	214.4	1581.9	228.9	1635.9	52
53	.8833	187.0	1475.7	200.5	1529.1	214.6	1582.8	229.1	1636.8	53
54	.9000	187.2	1476.6	200.8	1530.0	214.8	1583.7	229.4	1637.7	54
55	.9167	187.4	1477.4	201.0	1530.9	215.0	1584.6	229.6	1638.6	55
56	.9333	187.6	1478.3	201.2	1531.7	215.3	1585.5	229.9	1639.5	56
57	.9500	187.8	1479.2	201.4	1532.6	215.5	1586.3	230.1	1640.4	57
58	.9667	188.1	1480.1	201.7	1533.5	215.8	1587.2	230.4	1641.3	58
59	.9833	188.3	1481.0	201.9	1534.4	216.0	1588.1	230.6	1642.2	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	32°		33°		34°		35°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	230.9	1643.1	246.1	1697.3	261.8	1751.8	278.1	1806.7	0
1	.0167	231.1	1644.0	246.3	1698.2	262.0	1752.7	278.4	1807.6	1
2	.0333	231.4	1644.9	246.6	1699.1	262.3	1753.7	278.6	1808.5	2
3	.0500	231.6	1645.8	246.8	1700.0	262.6	1754.6	278.9	1809.4	3
4	.0667	231.9	1646.7	247.1	1700.9	262.9	1755.5	279.2	1810.3	4
5	.0833	232.1	1647.6	247.4	1701.8	263.1	1756.4	279.4	1811.2	5
6	.1000	232.4	1648.5	247.7	1702.7	263.4	1757.3	279.7	1812.2	6
7	.1167	232.6	1649.4	247.9	1703.6	263.7	1758.2	280.0	1813.1	7
8	.1333	232.9	1650.3	248.2	1704.5	264.0	1759.1	280.3	1814.0	8
9	.1500	233.1	1651.2	248.4	1705.4	264.2	1760.0	280.6	1814.9	9
10	.1667	233.4	1652.1	248.7	1706.4	264.5	1761.0	280.8	1815.8	10
11	.1833	233.6	1653.0	248.9	1707.3	264.7	1761.9	281.1	1816.7	11
12	.2000	233.9	1653.9	249.2	1708.2	265.0	1762.8	281.4	1817.7	12
13	.2167	234.1	1654.8	249.4	1709.1	265.3	1763.7	281.6	1818.6	13
14	.2333	234.4	1655.7	249.7	1710.0	265.6	1764.6	281.9	1819.5	14
15	.2500	234.6	1656.6	249.9	1710.9	265.9	1765.5	282.2	1820.4	15
16	.2667	234.9	1657.5	250.2	1711.8	266.1	1766.4	282.5	1821.3	16
17	.2833	235.1	1658.4	250.5	1712.7	266.4	1767.3	282.7	1822.2	17
18	.3000	235.4	1659.3	250.8	1713.6	266.7	1768.3	283.0	1823.2	18
19	.3167	235.6	1660.2	251.0	1714.5	266.9	1769.2	283.3	1824.1	19
20	.3333	235.9	1661.1	251.3	1715.5	267.2	1770.1	283.6	1825.0	20
21	.3500	236.1	1662.0	251.5	1716.4	267.4	1771.0	283.9	1825.9	21
22	.3667	236.4	1662.9	251.8	1717.3	267.7	1771.9	284.2	1826.8	22
23	.3833	236.6	1663.8	252.0	1718.2	268.0	1772.8	284.4	1827.7	23
24	.4000	236.9	1664.7	252.3	1719.1	268.3	1773.7	284.7	1828.7	24
25	.4167	237.1	1665.6	252.6	1720.0	268.6	1774.6	285.0	1829.6	25
26	.4333	237.4	1666.5	252.9	1720.9	268.8	1775.6	285.3	1830.5	26
27	.4500	237.6	1667.4	253.1	1721.8	269.1	1776.5	285.6	1831.4	27
28	.4667	237.9	1668.3	253.4	1722.7	269.3	1777.4	285.9	1832.3	28
29	.4833	238.1	1669.2	253.6	1723.6	269.6	1778.3	286.1	1833.2	29
30	.5000	238.4	1670.1	253.9	1724.6	269.9	1779.2	286.4	1834.2	30
31	.5167	238.7	1671.0	254.1	1725.5	270.1	1780.1	286.7	1835.1	31
32	.5333	239.0	1671.9	254.4	1726.4	270.4	1781.0	287.0	1836.0	32
33	.5500	239.2	1672.8	254.7	1727.3	270.7	1781.9	287.2	1836.9	33
34	.5667	239.5	1673.7	255.0	1728.2	271.0	1782.9	287.5	1837.8	34
35	.5833	239.7	1674.6	255.2	1729.1	271.2	1783.8	287.8	1838.7	35
36	.6000	240.0	1675.5	255.5	1730.0	271.5	1784.7	288.1	1839.7	36
37	.6167	240.2	1676.4	255.7	1730.9	271.7	1785.6	288.4	1840.6	37
38	.6333	240.5	1677.4	256.0	1731.8	272.0	1786.5	288.7	1841.5	38
39	.6500	240.7	1678.3	256.2	1732.7	272.3	1787.4	289.0	1842.4	39
40	.6667	241.0	1679.2	256.5	1733.6	272.6	1788.4	289.2	1843.4	40
41	.6833	241.2	1680.1	256.8	1734.5	272.9	1789.3	289.5	1844.3	41
42	.7000	241.5	1681.0	257.1	1735.5	273.1	1790.2	289.8	1845.2	42
43	.7167	241.7	1681.9	257.3	1736.4	273.4	1791.1	290.1	1846.1	43
44	.7333	242.0	1682.8	257.6	1737.3	273.7	1792.0	290.4	1847.1	44
45	.7500	242.2	1683.7	257.8	1738.2	274.0	1792.9	290.6	1848.0	45
46	.7667	242.5	1684.6	258.1	1739.1	274.2	1793.9	290.9	1848.9	46
47	.7833	242.7	1685.5	258.3	1740.0	274.5	1794.8	291.2	1849.8	47
48	.8000	243.0	1686.4	258.6	1740.9	274.8	1795.7	291.5	1850.7	48
49	.8167	243.2	1687.3	258.9	1741.8	275.0	1796.6	291.8	1851.6	49
50	.8333	243.5	1688.2	259.2	1742.7	275.3	1797.5	292.0	1852.6	50
51	.8500	243.8	1689.1	259.4	1743.6	275.6	1798.4	292.3	1853.5	51
52	.8667	244.1	1690.0	259.7	1744.6	275.9	1799.3	292.6	1854.4	52
53	.8833	244.3	1690.9	259.9	1745.5	276.1	1800.2	292.9	1855.3	53
54	.9000	244.6	1691.8	260.2	1746.4	276.4	1801.2	293.2	1856.3	54
55	.9167	244.8	1692.7	260.5	1747.3	276.7	1802.1	293.4	1857.2	55
56	.9333	245.1	1693.7	260.8	1748.2	277.0	1803.0	293.7	1858.1	56
57	.9500	245.3	1694.6	261.0	1749.1	277.3	1803.9	294.0	1859.0	57
58	.9667	245.6	1695.5	261.3	1750.0	277.5	1804.8	294.3	1859.9	58
59	.9833	245.8	1696.4	261.5	1750.9	277.8	1805.7	294.6	1860.8	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	36° Ext.	36° Tan.	37° Ext.	37° Tan.	38° Ext.	38° Tan.	39° Ext.	39° Tan.	Minutes
0	.0000	294.9	1861.8	312.3	1917.3	330.2	1973.0	348.7	2029.1	0
1	.0167	295.2	1862.7	312.5	1918.2	330.5	1973.9	349.0	2030.0	1
2	.0333	295.4	1863.6	312.8	1919.1	330.8	1974.9	349.3	2031.0	2
3	.0500	295.7	1864.5	313.1	1920.0	331.1	1975.8	349.6	2031.9	3
4	.0667	296.0	1865.5	313.4	1921.0	331.4	1976.7	349.9	2032.9	4
5	.0833	296.3	1866.4	313.7	1921.9	331.7	1977.6	350.3	2033.8	5
6	.1000	296.6	1867.3	314.0	1922.8	332.0	1978.6	350.6	2034.7	6
7	.1167	296.9	1868.2	314.3	1923.7	332.3	1979.5	350.9	2035.6	7
8	.1333	297.2	1869.2	314.6	1924.7	332.6	1980.5	351.2	2036.6	8
9	.1500	297.5	1870.1	314.9	1925.6	332.9	1981.4	351.5	2037.5	9
10	.1667	297.7	1871.0	315.2	1926.5	333.2	1982.3	351.8	2038.5	10
11	.1833	298.0	1871.9	315.5	1927.4	333.5	1983.2	352.1	2039.4	11
12	.2000	298.3	1872.9	315.8	1928.4	333.8	1984.2	352.4	2040.4	12
13	.2167	298.6	1873.8	316.1	1929.3	334.2	1985.1	352.8	2041.3	13
14	.2333	298.9	1874.7	316.4	1930.2	334.5	1986.1	353.1	2042.3	14
15	.2500	299.2	1875.6	316.7	1931.1	334.8	1987.0	353.4	2043.2	15
16	.2667	299.5	1876.5	317.0	1932.1	335.1	1987.9	353.7	2044.1	16
17	.2833	299.7	1877.4	317.2	1933.0	335.4	1988.8	354.0	2045.0	17
18	.3000	300.0	1878.4	317.5	1933.9	335.7	1989.8	354.3	2046.0	18
19	.3167	300.3	1879.3	317.8	1934.8	336.0	1990.7	354.6	2046.9	19
20	.3333	300.6	1880.2	318.1	1935.8	336.3	1991.7	354.9	2047.9	20
21	.3500	300.9	1881.1	318.4	1936.7	336.6	1992.6	355.3	2048.8	21
22	.3667	301.2	1882.1	318.7	1937.6	336.9	1993.6	355.6	2049.8	22
23	.3833	301.5	1883.0	319.0	1938.5	337.2	1994.5	355.9	2050.7	23
24	.4000	301.8	1883.9	319.3	1939.5	337.5	1995.4	356.2	2051.7	24
25	.4167	302.0	1884.8	319.6	1940.4	337.8	1996.3	356.6	2052.6	25
26	.4333	302.3	1885.8	319.9	1941.3	338.1	1997.3	356.9	2053.5	26
27	.4500	302.6	1886.7	320.2	1942.2	338.4	1998.2	357.2	2054.4	27
28	.4667	302.9	1887.6	320.5	1943.2	338.7	1999.2	357.5	2055.4	28
29	.4833	303.2	1888.5	320.8	1944.1	339.1	2000.1	357.8	2056.3	29
30	.5000	303.5	1889.5	321.1	1945.0	339.4	2001.0	358.1	2057.3	30
31	.5167	303.8	1890.4	321.4	1945.9	339.7	2001.9	358.4	2058.2	31
32	.5333	304.1	1891.3	321.7	1946.9	340.0	2002.9	358.8	2059.2	32
33	.5500	304.3	1892.2	322.0	1947.8	340.3	2003.8	359.1	2060.1	33
34	.5667	304.6	1893.2	322.3	1948.8	340.6	2004.8	359.4	2061.1	34
35	.5833	304.9	1894.1	322.6	1949.7	340.9	2005.7	359.8	2062.0	35
36	.6000	305.2	1895.0	322.9	1950.6	341.2	2006.6	360.1	2063.0	36
37	.6167	305.5	1895.9	323.2	1951.5	341.5	2007.5	360.4	2063.9	37
38	.6333	305.8	1896.9	323.5	1952.5	341.8	2008.5	360.7	2064.8	38
39	.6500	306.1	1897.8	323.8	1953.4	342.1	2009.4	361.0	2065.7	39
40	.6667	306.4	1898.7	324.2	1954.4	342.4	2010.4	361.3	2066.7	40
41	.6833	306.7	1899.6	324.5	1955.3	342.8	2011.3	361.6	2067.6	41
42	.7000	307.0	1900.6	324.8	1956.2	343.1	2012.3	362.0	2068.6	42
43	.7167	307.2	1901.5	325.1	1957.1	343.4	2013.2	362.3	2069.5	43
44	.7333	307.5	1902.4	325.4	1958.1	343.7	2014.1	362.6	2070.5	44
45	.7500	307.8	1903.3	325.7	1959.0	344.0	2015.0	363.0	2071.4	45
46	.7667	308.1	1904.3	326.0	1960.0	344.3	2016.0	363.3	2072.4	46
47	.7833	308.4	1905.2	326.3	1960.9	344.6	2016.9	363.6	2073.3	47
48	.8000	308.7	1906.1	326.6	1961.8	344.9	2017.9	363.9	2074.2	48
49	.8167	309.0	1907.0	326.9	1962.7	345.3	2018.8	364.2	2075.1	49
50	.8333	309.3	1908.0	327.2	1963.7	345.6	2019.7	364.5	2076.1	50
51	.8500	309.6	1908.9	327.5	1964.6	345.9	2020.6	364.9	2077.0	51
52	.8667	309.9	1909.8	327.8	1965.5	346.2	2021.6	365.2	2078.0	52
53	.8833	310.2	1910.7	328.1	1966.4	346.5	2022.5	365.5	2078.9	53
54	.9000	310.5	1911.7	328.4	1967.4	346.8	2023.5	365.8	2079.9	54
55	.9167	310.8	1912.6	328.7	1968.3	347.1	2024.4	366.2	2080.8	55
56	.9333	311.1	1913.5	329.0	1969.3	347.4	2025.4	366.5	2081.8	56
57	.9500	311.4	1914.4	329.3	1970.2	347.8	2026.3	366.8	2082.7	57
58	.9667	311.7	1915.4	329.6	1971.1	348.1	2027.2	367.1	2083.7	58
59	.9833	312.0	1916.3	329.9	1972.0	348.4	2028.1	367.4	2084.6	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	40°		41°		42°		43°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	367.7	2085.5	387.4	2142.3	407.7	2199.5	428.6	2257.1	0
1	.0167	368.0	2086.4	387.8	2143.2	408.0	2200.4	429.0	2258.0	1
2	.0333	368.4	2087.4	388.1	2144.2	408.3	2201.4	429.3	2259.0	2
3	.0500	368.7	2088.3	388.5	2145.1	408.7	2202.3	429.7	2260.0	3
4	.0667	369.0	2089.3	388.8	2146.1	409.0	2203.3	430.0	2261.0	4
5	.0833	369.4	2090.2	389.1	2147.0	409.4	2204.3	430.4	2261.9	5
6	.1000	369.7	2091.2	389.4	2148.0	409.7	2205.3	430.7	2262.9	6
7	.1167	370.0	2092.1	389.8	2148.9	410.1	2206.2	431.1	2263.8	7
8	.1333	370.3	2093.1	390.1	2149.9	410.4	2207.2	431.4	2264.8	8
9	.1500	370.7	2094.0	390.4	2150.9	410.8	2208.1	431.8	2265.7	9
10	.1667	371.0	2095.0	390.7	2151.9	411.1	2209.1	432.1	2266.7	10
11	.1833	371.3	2095.9	391.1	2152.8	411.5	2210.0	432.4	2267.7	11
12	.2000	371.6	2096.9	391.4	2153.8	411.8	2211.0	432.8	2268.7	12
13	.2167	372.0	2097.8	391.8	2154.7	412.2	2211.9	433.2	2269.6	13
14	.2333	372.3	2098.8	392.1	2155.7	412.5	2212.9	433.5	2270.6	14
15	.2500	372.6	2099.7	392.4	2156.6	412.9	2213.9	433.9	2271.5	15
16	.2667	372.9	2100.7	392.7	2157.6	413.2	2214.9	434.2	2272.5	16
17	.2833	373.3	2101.6	393.1	2158.5	413.6	2215.8	434.6	2273.5	17
18	.3000	373.6	2102.6	393.4	2159.5	413.9	2216.8	434.9	2274.5	18
19	.3167	374.0	2103.5	393.7	2160.4	414.3	2217.7	435.3	2275.4	19
20	.3333	374.3	2104.5	394.1	2161.4	414.6	2218.7	435.6	2276.4	20
21	.3500	374.6	2105.4	394.4	2162.3	415.0	2219.6	436.0	2277.3	21
22	.3667	374.9	2106.3	394.7	2163.3	415.3	2220.6	436.3	2278.3	22
23	.3833	375.3	2107.2	395.1	2164.2	415.7	2221.5	436.7	2279.2	23
24	.4000	375.6	2108.2	395.4	2165.2	416.0	2222.5	437.0	2280.2	24
25	.4167	375.9	2109.1	395.8	2166.1	416.3	2223.4	437.4	2281.2	25
26	.4333	376.2	2110.1	396.1	2167.1	416.6	2224.4	437.8	2282.2	26
27	.4500	376.6	2111.0	396.5	2168.0	417.0	2225.4	438.2	2283.1	27
28	.4667	376.9	2112.0	396.8	2169.0	417.3	2226.4	438.5	2284.1	28
29	.4833	377.2	2112.9	397.2	2169.9	417.7	2227.3	438.9	2285.0	29
30	.5000	377.5	2113.9	397.5	2170.9	418.0	2228.3	439.2	2286.0	30
31	.5167	377.9	2114.8	397.8	2171.8	418.4	2229.2	439.6	2287.0	31
32	.5333	378.2	2115.8	398.1	2172.8	418.7	2230.2	439.9	2288.0	32
33	.5500	378.5	2116.7	398.5	2173.7	419.1	2231.1	440.3	2288.9	33
34	.5667	378.8	2117.7	398.8	2174.7	419.4	2232.1	440.6	2289.9	34
35	.5833	379.2	2118.6	399.2	2175.6	419.8	2233.0	441.0	2290.8	35
36	.6000	379.5	2119.6	399.5	2176.6	420.1	2234.0	441.4	2291.8	36
37	.6167	379.8	2120.5	399.9	2177.5	420.5	2235.0	441.8	2292.8	37
38	.6333	380.1	2121.5	400.2	2178.5	420.8	2236.0	442.1	2293.8	38
39	.6500	380.5	2122.4	400.6	2179.4	421.2	2236.9	442.5	2294.7	39
40	.6667	380.8	2123.4	400.9	2180.4	421.5	2237.9	442.8	2295.7	40
41	.6833	381.1	2124.3	401.2	2181.4	421.9	2238.8	443.2	2296.7	41
42	.7000	381.4	2125.3	401.5	2182.4	422.2	2239.8	443.5	2297.7	42
43	.7167	381.8	2126.2	401.9	2183.3	422.6	2240.7	443.9	2298.6	43
44	.7333	382.1	2127.2	402.2	2184.3	422.9	2241.7	444.2	2299.6	44
45	.7500	382.5	2128.1	402.6	2185.2	423.3	2242.6	444.6	2300.5	45
46	.7667	382.8	2129.1	402.9	2186.2	423.6	2243.6	445.0	2301.5	46
47	.7833	383.1	2130.0	403.3	2187.1	424.0	2244.6	445.4	2302.5	47
48	.8000	383.4	2131.0	403.6	2188.1	424.3	2245.6	445.7	2303.5	48
49	.8167	383.8	2131.9	404.0	2189.0	424.7	2246.5	446.1	2304.4	49
50	.8333	384.1	2132.9	404.3	2190.0	425.0	2247.5	446.4	2305.4	50
51	.8500	384.5	2133.8	404.6	2190.9	425.4	2248.4	446.8	2306.3	51
52	.8667	384.8	2134.7	404.9	2191.9	425.7	2249.4	447.1	2307.3	52
53	.8833	385.1	2135.6	405.3	2192.8	426.1	2250.3	447.5	2308.3	53
54	.9000	385.4	2136.6	405.6	2193.8	426.4	2251.3	447.8	2309.3	54
55	.9167	385.8	2137.5	406.0	2194.7	426.8	2252.3	448.2	2310.2	55
56	.9333	386.1	2138.5	406.3	2195.7	427.1	2253.3	448.6	2311.2	56
57	.9500	386.5	2139.4	406.7	2196.6	427.5	2254.2	449.0	2312.1	57
58	.9667	386.8	2140.4	407.0	2197.6	427.8	2255.2	449.3	2313.1	58
59	.9833	387.1	2141.3	407.4	2198.5	428.2	2256.1	449.7	2314.1	59

Use 100′ Chords up to 8° Curves   Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves   Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	44°		45°		46°		47°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	450.0	2315.1	472.1	2373.4	494.8	2432.2	518.3	2491.5	0
1	.0167	450.4	2316.0	472.5	2374.4	495.2	2433.2	518.7	2492.4	1
2	.0333	450.7	2317.0	472.9	2375.4	495.6	2434.2	519.0	2493.4	2
3	.0500	451.1	2318.0	473.3	2376.3	496.0	2435.1	519.4	2494.4	3
4	.0667	451.5	2319.0	473.6	2377.3	496.4	2436.1	519.8	2495.4	4
5	.0833	451.9	2319.9	474.0	2378.3	496.7	2437.1	520.2	2496.4	5
6	.1000	452.2	2320.9	474.4	2379.3	497.2	2438.1	520.6	2497.4	6
7	.1167	452.6	2321.8	474.8	2380.2	497.6	2439.1	521.0	2498.4	7
8	.1333	452.9	2322.8	475.1	2381.2	497.9	2440.1	521.4	2499.4	8
9	.1500	453.3	2323.8	475.5	2382.2	498.3	2441.1	521.8	2500.4	9
10	.1667	453.7	2324.8	475.9	2383.2	498.7	2442.1	522.2	2501.4	10
11	.1833	454.1	2325.7	476.3	2384.2	499.1	2443.0	522.6	2502.4	11
12	.2000	454.4	2326.7	476.6	2385.2	499.5	2444.0	523.0	2503.4	12
13	.2167	454.8	2327.7	477.0	2386.1	499.9	2445.0	523.4	2504.4	13
14	.2333	455.1	2328.7	477.4	2387.1	500.3	2446.0	523.8	2505.4	14
15	.2500	455.5	2329.6	477.8	2388.1	500.7	2447.0	524.2	2506.3	15
16	.2667	455.9	2330.6	478.1	2389.1	501.0	2448.0	524.6	2507.3	16
17	.2833	456.3	2331.6	478.5	2390.0	501.4	2449.0	525.0	2508.3	17
18	.3000	456.6	2332.6	478.9	2391.0	501.8	2449.9	525.4	2509.3	18
19	.3167	457.0	2333.5	479.3	2392.0	502.2	2450.9	525.8	2510.3	19
20	.3333	457.3	2334.5	479.6	2393.0	502.6	2451.9	526.2	2511.3	20
21	.3500	457.7	2335.4	480.0	2393.9	503.0	2452.9	526.6	2512.3	21
22	.3667	458.1	2336.4	480.4	2394.9	503.4	2453.9	527.0	2513.3	22
23	.3833	458.5	2337.4	480.8	2395.9	503.8	2454.9	527.4	2514.3	23
24	.4000	458.8	2338.4	481.1	2396.9	504.1	2455.9	527.8	2515.3	24
25	.4167	459.2	2339.3	481.5	2397.8	504.5	2456.8	528.2	2516.3	25
26	.4333	459.5	2340.3	481.9	2398.8	504.9	2457.8	528.6	2517.3	26
27	.4500	459.9	2341.3	482.3	2399.8	505.3	2458.8	529.0	2518.3	27
28	.4667	460.3	2342.3	482.6	2400.8	505.7	2459.8	529.4	2519.3	28
29	.4833	460.7	2343.2	483.0	2401.8	506.1	2460.8	529.8	2520.2	29
30	.5000	461.0	2344.2	483.4	2402.8	506.5	2461.8	530.2	2521.2	30
31	.5167	461.4	2345.1	483.8	2403.7	506.9	2462.8	530.6	2522.2	31
32	.5333	461.7	2346.1	484.2	2404.7	507.3	2463.8	531.0	2523.2	32
33	.5500	462.1	2347.1	484.6	2405.7	507.7	2464.7	531.4	2524.2	33
34	.5667	462.5	2348.1	484.9	2406.7	508.0	2465.7	531.8	2525.2	34
35	.5833	462.9	2349.0	485.3	2407.6	508.4	2466.7	532.2	2526.2	35
36	.6000	463.2	2350.0	485.7	2408.6	508.8	2467.7	532.6	2527.2	36
37	.6167	463.6	2351.0	486.1	2409.6	509.2	2468.7	533.0	2528.2	37
38	.6333	463.9	2352.0	486.5	2410.6	509.6	2469.7	533.4	2529.2	38
39	.6500	464.3	2352.9	486.9	2411.6	510.0	2470.7	533.8	2530.2	39
40	.6667	464.7	2353.9	487.2	2412.6	510.4	2471.7	534.2	2531.2	40
41	.6833	465.0	2354.9	487.6	2413.5	510.8	2472.6	534.6	2532.2	41
42	.7000	465.4	2355.9	488.0	2414.5	511.1	2473.6	535.0	2533.2	42
43	.7167	465.8	2356.8	488.4	2415.5	511.5	2474.6	535.4	2534.2	43
44	.7333	466.2	2357.8	488.7	2416.5	511.9	2475.6	535.8	2535.2	44
45	.7500	466.5	2358.8	489.1	2417.5	512.3	2476.6	536.2	2536.2	45
46	.7667	466.9	2359.8	489.5	2418.5	512.7	2477.6	536.6	2537.2	46
47	.7833	467.3	2360.7	489.9	2419.4	513.1	2478.6	537.0	2538.2	47
48	.8000	467.7	2361.7	490.3	2420.4	513.5	2479.6	537.4	2539.2	48
49	.8167	468.0	2362.7	490.7	2421.4	513.9	2480.6	537.8	2540.2	49
50	.8333	468.4	2363.7	491.0	2422.4	514.3	2481.6	538.2	2541.2	50
51	.8500	468.8	2364.6	491.4	2423.4	514.7	2482.5	538.6	2542.2	51
52	.8667	469.1	2365.6	491.8	2424.4	515.1	2483.5	539.0	2543.2	52
53	.8833	469.5	2366.6	492.2	2425.3	515.5	2484.5	539.4	2544.2	53
54	.9000	469.9	2367.6	492.5	2426.3	515.9	2485.5	539.8	2545.2	54
55	.9167	470.3	2368.5	492.9	2427.3	516.3	2486.5	540.2	2546.2	55
56	.9333	470.6	2369.5	493.3	2428.3	516.7	2487.5	540.6	2547.2	56
57	.9500	471.0	2370.5	493.7	2429.2	517.1	2488.5	541.0	2548.2	57
58	.9667	471.4	2371.5	494.1	2430.2	517.5	2489.5	541.4	2549.2	58
59	.9833	471.8	2372.4	494.5	2431.2	517.9	2490.5	541.9	2550.1	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	48°		49°		50°		51°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	542.3	2551.1	567.0	2611.3	592.4	2671.9	618.5	2733.0	0
1	.0167	542.7	2552.1	567.4	2612.3	592.8	2672.9	618.9	2734.1	1
2	.0333	543.1	2553.1	567.8	2613.3	593.2	2673.9	619.3	2735.1	2
3	.0500	543.5	2554.1	568.3	2614.3	593.7	2675.0	619.8	2736.1	3
4	0667	543.9	2555.1	568.7	2615.3	594.1	2676.0	620.2	2737.1	4
5	.0833	544.3	2556.1	569.1	2616.3	594.5	2677.0	620.7	2738.2	5
6	.1000	544.7	2557.1	569.5	2617.3	594.9	2678.0	621.1	2739.2	6
7	.1167	545.1	2558.1	569.9	2618.3	595.4	2679.0	621.6	2740.2	7
8	.1333	545.5	2559.1	570.3	2619.3	595.8	2680.0	622.0	2741.2	8
9	.1500	546.0	2560.1	570.8	2620.4	596.2	2681.1	622.5	2742.3	9
10	.1667	546.4	2561.1	571.2	2621.4	596.7	2682.1	622.9	2743.3	10
11	.1833	546.8	2562.1	571.6	2622.4	597.1	2683.1	623.3	2744.3	11
12	.2000	547.2	2563.1	572.0	2623.4	597.5	2684.1	623.7	2745.3	12
13	.2167	547.6	2564.1	572.4	2624.4	598.0	2685.1	624.2	2746.4	13
14	.2333	548.0	2565.1	572.8	2625.4	598.4	2686.1	624.6	2747.4	14
15	.2500	548.4	2566.1	573.3	2626.4	598.9	2687.2	625.1	2748.4	15
16	.2667	548.8	2567.1	573.7	2627.4	599.3	2688.2	625.5	2749.4	16
17	.2833	549.2	2568.1	574.1	2628.4	599.7	2689.2	626.0	2750.5	17
18	.3000	549.6	2569.1	574.5	2629.4	600.1	2690.2	626.4	2751.5	18
19	.3167	550.1	2570.1	574.9	2630.4	600.6	2691.3	626.9	2752.5	19
20	.3333	550.5	2571.1	575.3	2631.4	601.0	2692.3	627.3	2753.5	20
21	.3500	550.9	2572.1	575.8	2632.5	601.5	2693.3	627.8	2754.6	21
22	.3667	551.3	2573.1	576.2	2633.5	601.9	2694.3	628.2	2755.6	22
23	.3833	551.7	2574.1	576.6	2634.5	602.3	2695.3	628.7	2756.7	23
24	.4000	552.1	2575.1	577.0	2635.5	602.7	2696.3	629.1	2757.7	24
25	.4167	552.5	2576.1	577.5	2636.5	603.2	2697.4	629.6	2758.7	25
26	.4333	552.9	2577.1	577.9	2637.5	603.6	2698.4	630.0	2759.7	26
27	.4500	553.3	2578.1	578.3	2638.5	604.1	2699.4	630.5	2760.8	27
28	.4667	553.7	2579.1	578.7	2639.5	604.5	2700.4	630.9	2761.8	28
29	.4833	554.2	2580.1	579.2	2640.5	604.9	2701.4	631.4	2762.8	29
30	.5000	554.6	2581.1	579.6	2641.5	605.3	2702.4	631.8	2763.8	30
31	.5167	555.0	2582.1	580.0	2642.5	605.8	2703.5	632.3	2764.9	31
32	.5333	555.4	2583.1	580.4	2643.5	606.2	2704.5	632.7	2765.9	32
33	.5500	555.8	2584.1	580.9	2644.6	606.6	2705.5	633.2	2766.9	33
34	.5667	556.2	2585.1	581.3	2645.6	607.0	2706.5	633.6	2767.9	34
35	.5833	556.6	2586.2	581.7	2646.6	607.5	2707.6	634.1	2769.0	35
36	.6000	557.0	2587.2	582.1	2647.6	607.9	2708.6	634.5	2770.0	36
37	.6167	557.4	2588.2	582.6	2648.6	608.4	2709.6	634.9	2771.0	37
38	.6333	557.8	2589.2	583.0	2649.6	608.8	2710.6	635.3	2772.0	38
39	.6500	558.3	2590.2	583.4	2650.6	609.3	2711.6	635.8	2773.1	39
40	.6667	558.7	2591.2	583.8	2651.6	609.7	2712.6	636.2	2774.1	40
41	.6833	559.1	2592.2	584.3	2652.7	610.1	2713.7	636.7	2775.2	41
42	.7000	559.5	2593.2	584.7	2653.7	610.5	2714.7	637.1	2776.2	42
43	.7167	559.9	2594.2	585.1	2654.7	611.0	2715.7	637.5	2777.2	43
44	.7333	560.3	2595.2	585.5	2655.7	611.4	2716.7	638.0	2778.2	44
45	.7500	560.8	2596.2	586.0	2656.7	611.9	2717.8	638.5	2779.3	45
46	.7667	561.2	2597.2	586.4	2657.7	612.3	2718.8	638.9	2780.3	46
47	.7833	561.6	2598.2	586.8	2658.7	612.8	2719.8	639.4	2781.3	47
48	.8000	562.0	2599.2	587.2	2659.7	613.2	2720.8	639.8	2782.3	48
49	.8167	562.4	2600.2	587.7	2660.8	613.7	2721.8	640.3	2783.4	49
50	.8333	562.8	2601.2	588.1	2661.8	614.1	2722.8	640.7	2784.4	50
51	.8500	563.3	2602.2	588.5	2662.8	614.5	2723.9	641.2	2785.4	51
52	.8667	563.7	2603.2	588.9	2663.8	614.9	2724.9	641.6	2786.4	52
53	.8833	564.1	2604.2	589.4	2664.8	615.4	2725.9	642.1	2787.5	53
54	.9000	564.5	2605.2	589.8	2665.8	615.8	2726.9	642.5	2788.5	54
55	.9167	564.9	2606.2	590.2	2666.8	616.3	2728.0	643.0	2789.6	55
56	.9333	565.3	2607.2	590.6	2667.8	616.7	2729.0	643.4	2790.6	56
57	.9500	565.8	2608.3	591.1	2668.9	617.2	2730.0	643.9	2791.6	57
58	.9667	566.2	2609.3	591.5	2669.9	617.6	2731.0	644.3	2792.6	58
59	.9833	566.6	2610.3	592.0	2670.9	618.1	2732.0	644.8	2793.7	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	52° Ext.	52° Tan.	53° Ext.	53° Tan.	54° Ext.	54° Tan.	55° Ext.	55° Tan.	Minutes
0	.0000	645.2	2794.7	672.7	2856.9	700.9	2919.5	729.9	2982.8	0
1	.0167	645.7	2795.8	673.2	2857.9	701.4	2920.6	730.4	2983.9	1
2	.0333	646.1	2796.8	673.7	2858.9	701.9	2921.6	730.9	2984.9	2
3	.0500	646.6	2797.8	674.2	2860.0	702.4	2922.7	731.4	2986.0	3
4	.0667	647.0	2798.8	674.6	2861.0	702.8	2923.8	731.9	2987.1	4
5	.0833	647.5	2799.9	675.1	2862.1	703.3	2924.9	732.4	2988.2	5
6	.1000	647.9	2800.9	675.5	2863.1	703.8	2925.9	732.9	2989.2	6
7	.1167	648.4	2802.0	676.0	2864.2	704.3	2927.0	733.4	2990.3	7
8	.1333	648.9	2803.0	676.4	2865.2	704.8	2928.0	733.8	2991.3	8
9	.1500	649.4	2804.0	676.9	2866.3	705.3	2929.1	734.3	2992.4	9
10	.1667	649.8	2805.0	677.4	2867.3	705.7	2930.1	734.8	2993.4	10
11	.1833	650.3	2806.1	677.9	2868.4	706.2	2931.2	735.3	2994.5	11
12	.2000	650.7	2807.1	678.3	2869.4	706.7	2932.2	735.8	2995.5	12
13	.2167	651.2	2808.2	678.8	2870.5	707.2	2933.3	736.3	2996.6	13
14	.2333	651.6	2809.2	679.2	2871.5	707.7	2934.3	736.8	2997.7	14
15	.2500	652.1	2810.2	679.7	2872.5	708.2	2935.4	737.3	2998.8	15
16	.2667	652.5	2811.2	680.2	2873.5	708.6	2936.4	737.8	2999.8	16
17	.2833	653.0	2812.3	680.7	2874.6	709.1	2937.5	738.2	3000.9	17
18	.3000	653.4	2813.3	681.1	2875.6	709.6	2938.5	738.7	3001.9	18
19	.3167	653.9	2814.4	681.6	2876.7	710.1	2939.6	739.2	3003.0	19
20	.3333	654.3	2815.4	682.0	2877.7	710.5	2940.6	739.7	3004.0	20
21	.3500	654.8	2816.4	682.5	2878.8	711.0	2941.7	740.2	3005.1	21
22	.3667	655.2	2817.4	683.0	2879.8	711.5	2942.7	740.7	3006.2	22
23	.3833	655.7	2818.5	683.5	2880.9	712.0	2943.8	741.2	3007.3	23
24	.4000	656.2	2819.5	683.9	2881.9	712.5	2944.8	741.7	3008.3	24
25	.4167	656.7	2820.6	684.4	2883.0	713.0	2945.9	742.2	3009.4	25
26	.4333	657.1	2821.6	684.9	2884.0	713.4	2946.9	742.7	3010.4	26
27	.4500	657.6	2822.6	685.4	2885.1	713.9	2948.0	743.2	3011.5	27
28	.4667	658.0	2823.6	685.8	2886.1	714.4	2949.0	743.7	3012.5	28
29	.4833	658.5	2824.7	686.3	2887.1	714.9	2950.1	744.2	3013.6	29
30	.5000	658.9	2825.7	686.7	2888.1	715.3	2951.1	744.7	3014.7	30
31	.5167	659.4	2826.8	687.2	2889.2	715.8	2952.2	745.2	3015.8	31
32	.5333	659.8	2827.8	687.7	2890.2	716.3	2953.2	745.7	3016.8	32
33	.5500	660.3	2828.8	688.2	2891.3	716.8	2954.3	746.2	3017.9	33
34	.5667	660.7	2829.8	688.6	2892.3	717.3	2955.3	746.7	3018.9	34
35	.5833	661.2	2830.9	689.1	2893.4	717.8	2956.4	747.2	3020.0	35
36	.6000	661.6	2831.9	689.6	2894.4	718.2	2957.5	747.7	3021.1	36
37	.6167	662.1	2833.0	690.1	2895.5	718.7	2958.6	748.2	3022.1	37
38	.6333	662.5	2834.0	690.5	2896.5	719.2	2959.6	748.7	3023.2	38
39	.6500	663.0	2835.1	691.0	2897.6	719.7	2960.7	749.2	3024.3	39
40	.6667	663.5	2836.1	691.5	2898.6	720.2	2961.7	749.7	3025.3	40
41	.6833	664.0	2837.2	692.0	2899.7	720.7	2962.8	750.2	3026.4	41
42	.7000	664.4	2838.2	692.4	2900.7	721.1	2963.8	750.7	3027.5	42
43	.7167	664.9	2839.2	692.9	2901.8	721.6	2964.9	751.2	3028.6	43
44	.7333	665.3	2840.2	693.4	2902.8	722.1	2965.9	751.7	3029.6	44
45	.7500	665.8	2841.3	693.9	2903.9	722.6	2967.0	752.2	3030.7	45
46	.7667	666.2	2842.3	694.3	2904.9	723.1	2968.0	752.6	3031.7	46
47	.7833	666.7	2843.4	694.8	2906.0	723.6	2969.1	753.1	3032.8	47
48	.8000	667.2	2844.4	695.3	2907.0	724.1	2970.1	753.6	3033.8	48
49	.8167	667.7	2845.5	695.8	2908.1	724.6	2971.2	754.1	3035.0	49
50	.8333	668.1	2846.5	696.2	2909.1	725.0	2972.2	754.6	3036.0	50
51	.8500	668.6	2847.5	696.7	2910.2	725.5	2973.3	755.1	3037.1	51
52	.8667	669.0	2848.5	697.1	2911.2	726.0	2974.4	755.6	3038.1	52
53	.8833	669.5	2849.6	697.6	2912.3	726.5	2975.5	756.1	3039.2	53
54	.9000	669.9	2850.6	698.1	2913.3	727.0	2976.5	756.6	3040.2	54
55	.9167	670.4	2851.7	698.6	2914.4	727.5	2977.6	757.1	3041.3	55
56	.9333	670.9	2852.7	699.0	2915.4	728.0	2978.6	757.6	3042.4	56
57	.9500	671.4	2853.8	699.5	2916.5	728.5	2979.7	758.1	3043.5	57
58	.9667	671.8	2854.8	700.0	2917.5	729.0	2980.7	758.6	3044.5	58
59	.9833	672.3	2855.9	700.5	2918.5	729.5	2981.8	759.1	3045.6	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	56° Ext.	56° Tan.	57° Ext.	57° Tan.	58° Ext.	58° Tan.	59° Ext.	59° Tan.	Minutes
0	.0000	759.6	3046.6	790.2	3111.1	821.4	3176.1	853.5	3241.9	0
1	.0167	760.1	3047.7	790.7	3112.2	821.9	3177.2	854.0	3243.0	1
2	.0333	760.6	3048.8	791.2	3113.3	822.5	3178.3	854.6	3244.1	2
3	.0500	761.1	3049.9	791.7	3114.4	823.0	3179.4	855.1	3245.2	3
4	.0667	761.6	3050.9	792.2	3115.4	823.5	3180.5	855.7	3246.3	4
5	.0833	762.2	3052.0	792.8	3116.5	824.1	3181.6	856.2	3247.4	5
6	.1000	762.7	3053.1	793.3	3117.6	824.6	3182.7	856.8	3248.5	6
7	.1167	763.2	3054.2	793.8	3118.7	825.2	3183.8	857.3	3249.6	7
8	.1333	763.7	3055.2	794.3	3119.7	825.7	3184.9	857.9	3250.7	8
9	.1500	764.2	3056.3	794.8	3120.8	826.2	3186.0	858.5	3251.8	9
10	.1667	764.7	3057.4	795.3	3121.9	826.7	3187.1	859.0	3252.9	10
11	.1833	765.2	3058.5	795.8	3123.0	827.3	3188.2	859.5	3254.0	11
12	.2000	765.7	3059.5	796.3	3124.1	827.8	3189.2	860.0	3255.1	12
13	.2167	766.2	3060.6	796.9	3125.2	828.4	3190.3	860.6	3256.2	13
14	.2333	766.7	3061.6	797.4	3126.2	828.9	3191.4	861.1	3257.3	14
15	.2500	767.2	3062.7	797.9	3127.3	829.4	3192.5	861.7	3258.4	15
16	.2667	767.7	3063.8	798.4	3128.4	829.9	3193.6	862.2	3259.5	16
17	.2833	768.2	3064.9	798.9	3129.5	830.5	3194.7	862.8	3260.6	17
18	.3000	768.7	3065.9	799.4	3130.6	831.0	3195.8	863.3	3261.7	18
19	.3167	769.2	3067.0	799.9	3131.7	831.5	3196.9	863.8	3262.8	19
20	.3333	769.7	3068.1	800.5	3132.7	832.1	3198.0	864.4	3263.9	20
21	.3500	770.3	3069.2	801.0	3133.8	832.5	3199.1	864.9	3265.0	21
22	.3667	770.8	3070.2	801.5	3134.9	833.1	3200.2	865.5	3266.1	22
23	.3833	771.3	3071.3	802.0	3136.0	833.6	3201.3	866.0	3267.2	23
24	.4000	771.8	3072.4	802.5	3137.0	834.2	3202.4	866.6	3268.3	24
25	.4167	772.3	3073.5	803.1	3138.1	834.7	3203.5	867.1	3269.4	25
26	.4333	772.8	3074.5	803.6	3139.2	835.3	3204.5	867.7	3270.5	26
27	.4500	773.3	3075.6	804.2	3140.3	835.8	3205.6	868.2	3271.6	27
28	.4667	773.8	3076.6	804.7	3141.4	836.3	3206.7	868.8	3272.7	28
29	.4833	774.3	3077.7	805.2	3142.5	836.8	3207.8	869.3	3273.8	29
30	.5000	774.8	3078.8	805.7	3143.5	837.4	3208.9	869.9	3274.9	30
31	.5167	775.3	3079.9	806.3	3144.6	837.8	3210.0	870.5	3276.0	31
32	.5333	775.8	3080.9	806.8	3145.7	838.4	3211.1	871.0	3277.1	32
33	.5500	776.3	3082.0	807.3	3146.8	838.9	3212.2	871.6	3278.2	33
34	.5667	776.8	3083.1	807.8	3147.9	839.5	3213.3	872.1	3279.4	34
35	.5833	777.3	3084.2	808.3	3149.0	840.0	3214.4	872.7	3280.5	35
36	.6000	777.8	3085.2	808.8	3150.0	840.6	3215.5	873.2	3281.6	36
37	.6167	778.4	3086.3	809.4	3151.1	841.1	3216.6	873.8	3282.7	37
38	.6333	778.9	3087.4	809.9	3152.2	841.6	3217.7	874.3	3283.8	38
39	.6500	779.4	3088.5	810.4	3153.3	842.1	3218.8	874.9	3284.9	39
40	.6667	779.9	3089.6	810.9	3154.4	842.7	3219.9	875.4	3286.0	40
41	.6833	780.4	3090.7	811.5	3155.5	843.1	3221.0	876.0	3287.1	41
42	.7000	780.9	3091.7	812.0	3156.6	843.8	3222.1	876.5	3288.2	42
43	.7167	781.4	3092.8	812.5	3157.7	844.2	3223.2	877.0	3289.3	43
44	.7333	781.9	3093.9	813.0	3158.7	844.9	3224.3	877.6	3290.5	44
45	.7500	782.5	3095.0	813.6	3159.8	845.5	3225.4	878.1	3291.6	45
46	.7667	783.0	3096.0	814.1	3160.9	846.0	3226.5	878.7	3292.7	46
47	.7833	783.5	3097.1	814.6	3162.0	846.5	3227.6	879.2	3293.8	47
48	.8000	784.0	3098.2	815.1	3163.1	847.0	3228.7	879.8	3294.9	48
49	.8167	784.5	3099.3	815.7	3164.2	847.6	3229.8	880.3	3296.0	49
50	.8333	785.0	3100.3	816.2	3165.3	848.1	3230.9	880.9	3297.1	50
51	.8500	785.5	3101.4	816.7	3166.4	848.7	3232.0	881.5	3298.2	51
52	.8667	786.0	3102.5	817.2	3167.4	849.2	3233.1	882.0	3299.3	52
53	.8833	786.6	3103.6	817.8	3168.5	849.8	3234.2	882.6	3300.4	53
54	.9000	787.1	3104.6	818.3	3169.6	850.3	3235.3	883.1	3301.5	54
55	.9167	787.6	3105.7	818.8	3170.7	850.9	3236.4	883.7	3302.6	55
56	.9333	788.1	3106.8	819.3	3171.8	851.4	3237.5	884.2	3303.8	56
57	.9500	788.6	3107.9	819.9	3172.9	852.0	3238.6	884.8	3304.9	57
58	.9667	789.1	3108.9	820.4	3174.0	852.5	3239.7	885.3	3306.0	58
59	.9833	789.7	3110.0	820.9	3175.1	853.0	3240.8	885.9	3307.1	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	60° Ext.	60° Tan.	61° Ext.	61° Tan.	62° Ext.	62° Tan.	63° Ext.	63° Tan.	Minutes
0	.0000	886.4	3308.2	920.2	3375.2	954.8	3442.9	990.3	3511.3	0
1	.0167	886.9	3309.3	920.8	3376.3	955.4	3444.1	990.9	3512.4	1
2	.0333	887.5	3310.4	921.4	3377.4	956.0	3445.2	991.5	3513.6	2
3	.0500	888.1	3311.5	922.0	3378.5	956.6	3446.3	992.1	3514.8	3
4	.0667	888.7	3312.7	922.5	3379.7	957.2	3447.5	992.7	3515.9	4
5	.0833	889.3	3313.8	923.0	3380.8	957.7	3448.6	993.3	3517.1	5
6	.1000	889.8	3314.9	923.6	3381.9	958.3	3449.7	993.9	3518.2	6
7	.1167	890.3	3316.0	924.2	3383.1	958.9	3450.9	994.5	3519.3	7
8	.1333	890.9	3317.1	924.8	3384.2	959.5	3452.0	995.1	3520.5	8
9	.1500	891.5	3318.2	925.3	3385.3	960.1	3453.2	995.7	3521.6	9
10	.1667	892.0	3319.3	925.9	3386.4	960.7	3454.3	996.3	3522.8	10
11	.1833	892.6	3320.5	926.5	3387.5	961.3	3455.4	996.9	3524.0	11
12	.2000	893.1	3321.6	927.1	3388.7	961.9	3456.6	997.5	3525.1	12
13	.2167	893.7	3322.7	927.6	3389.8	962.4	3457.7	998.1	3526.2	13
14	.2333	894.3	3323.8	928.2	3390.9	963.0	3458.8	998.7	3527.4	14
15	.2500	894.8	3324.9	928.7	3392.1	963.6	3460.0	999.3	3528.6	15
16	.2667	895.4	3326.0	929.3	3393.2	964.2	3461.1	999.9	3529.7	16
17	.2833	895.9	3327.1	929.9	3394.3	964.8	3462.3	1000.5	3530.9	17
18	.3000	896.5	3328.3	930.5	3395.4	965.4	3463.4	1001.1	3532.0	18
19	.3167	897.0	3329.4	931.0	3396.6	966.0	3464.6	1001.7	3533.1	19
20	.3333	897.6	3330.5	931.6	3397.7	966.6	3465.7	1002.3	3534.3	20
21	.3500	898.2	3331.6	932.2	3398.8	967.2	3466.8	1002.9	3535.4	21
22	.3667	898.8	3332.7	932.8	3399.9	967.8	3467.9	1003.5	3536.6	22
23	.3833	899.3	3333.8	933.3	3401.1	968.3	3469.0	1004.1	3537.8	23
24	.4000	899.9	3334.9	933.9	3402.2	968.9	3470.2	1004.7	3538.9	24
25	.4167	900.5	3336.1	934.5	3403.3	969.5	3471.3	1005.3	3540.0	25
26	.4333	901.0	3337.2	935.1	3404.4	970.1	3472.5	1005.9	3541.2	26
27	.4500	901.6	3338.3	935.7	3405.6	970.7	3473.6	1006.5	3542.3	27
28	.4667	902.1	3339.4	936.3	3406.7	971.3	3474.7	1007.1	3543.5	28
29	.4833	902.7	3340.5	936.8	3407.8	971.9	3475.9	1007.8	3544.6	29
30	.5000	903.2	3341.6	937.4	3408.9	972.5	3477.0	1008.4	3545.8	30
31	.5167	903.8	3342.7	938.0	3410.1	973.0	3478.1	1009.0	3546.9	31
32	.5333	904.4	3343.9	938.6	3411.2	973.6	3479.3	1009.6	3548.1	32
33	.5500	904.9	3345.0	939.1	3412.3	974.2	3480.5	1010.2	3549.2	33
34	.5667	905.5	3346.1	939.7	3413.5	974.8	3481.6	1010.8	3550.4	34
35	.5833	906.1	3347.2	940.4	3414.6	975.4	3482.7	1011.4	3551.6	35
36	.6000	906.6	3348.3	940.9	3415.7	976.0	3483.9	1012.0	3552.7	36
37	.6167	907.2	3349.5	941.5	3416.8	976.6	3485.0	1012.6	3553.8	37
38	.6333	907.7	3350.6	942.1	3418.0	977.2	3486.2	1013.2	3555.0	38
39	.6500	908.2	3351.7	942.6	3419.2	977.8	3487.4	1013.9	3556.2	39
40	.6667	908.8	3352.8	943.2	3420.3	978.4	3488.5	1014.5	3557.3	40
41	.6833	909.4	3353.9	943.8	3421.4	979.0	3489.6	1015.1	3558.4	41
42	.7000	910.0	3355.0	944.4	3422.5	979.6	3490.7	1015.7	3559.6	42
43	.7167	910.6	3356.1	944.9	3423.6	980.2	3491.9	1016.3	3560.8	43
44	.7333	911.1	3357.3	945.5	3424.8	980.8	3493.0	1016.9	3562.0	44
45	.7500	911.7	3358.4	946.1	3426.0	981.4	3494.2	1017.5	3563.2	45
46	.7667	912.3	3359.5	946.7	3427.1	982.0	3495.3	1018.1	3564.3	46
47	.7833	912.8	3360.6	947.2	3428.2	982.6	3496.4	1018.7	3565.5	47
48	.8000	913.4	3361.8	947.8	3429.3	983.2	3497.6	1019.3	3566.6	48
49	.8167	913.9	3362.9	948.4	3430.4	983.8	3498.7	1020.0	3567.7	49
50	.8333	914.5	3364.0	949.0	3431.6	984.4	3499.9	1020.6	3568.9	50
51	.8500	915.1	3365.1	949.6	3432.8	984.9	3501.0	1021.2	3570.0	51
52	.8667	915.7	3366.2	950.2	3433.6	985.5	3502.2	1021.8	3571.2	52
53	.8833	916.2	3367.3	950.7	3434.0	986.1	3503.3	1022.4	3572.3	53
54	.9000	916.8	3368.5	951.3	3436.1	986.7	3504.5	1023.0	3573.5	54
55	.9167	917.4	3369.6	951.9	3437.2	987.3	3505.6	1023.6	3574.6	55
56	.9333	918.0	3370.7	952.5	3438.4	987.9	3506.8	1024.2	3575.8	56
57	.9500	918.6	3371.9	953.0	3439.6	988.5	3507.9	1024.8	3576.9	57
58	.9667	919.1	3373.0	953.6	3440.7	989.1	3509.0	1025.4	3578.1	58
59	.9833	919.6	3374.1	954.2	3441.8	989.7	3510.1	1026.1	3579.3	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	64°		65°		66°		67°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan	Ext.	Tan.	
0	.0000	1026.7	3580.4	1064.0	3650.4	1102.2	3721.1	1141.5	3792.6	0
1	.0167	1027.3	3581.6	1064.6	3651.6	1102.9	3722.3	1142.2	3793.8	1
2	.0333	1027.9	3582.8	1065.2	3652.8	1103.5	3723.4	1142.8	3795.0	2
3	.0500	1028.6	3583.9	1065.9	3654.0	1104.2	3724.6	1143.5	3796.2	3
4	.0667	1029.2	3585.1	1066.5	3655.1	1104.8	3725.8	1144.1	3797.4	4
5	.0833	1029.8	3586.3	1067.1	3656.3	1105.5	3727.0	1144.8	3798.6	5
6	.1000	1030.4	3587.4	1067.7	3657.5	1106.1	3728.2	1145.4	3799.8	6
7	.1167	1031.1	3588.6	1068.4	3658.6	1106.8	3729.4	1146.1	3801.0	7
8	.1333	1031.7	3589.7	1069.0	3659.8	1107.4	3730.6	1146.7	3802.2	8
9	.1500	1032.3	3590.9	1069.6	3661.0	1108.1	3731.7	1147.4	3803.4	9
10	.1667	1032.9	3592.1	1070.2	3662.2	1108.7	3732.9	1148.1	3804.6	10
11	.1833	1033.5	3593.3	1070.9	3663.4	1109.4	3734.1	1148.8	3805.8	11
12	.2000	1034.1	3594.4	1071.5	3664.5	1110.0	3735.3	1149.4	3807.0	12
13	.2167	1034.8	3595.5	1072.1	3665.7	1110.7	3736.5	1150.1	3808.2	13
14	.2333	1035.4	3596.7	1072.7	3666.9	1111.3	3737.7	1150.7	3809.4	14
15	.2500	1036.0	3597.9	1073.4	3668.0	1112.0	3738.9	1151.4	3810.6	15
16	.2667	1036.6	3599.1	1074.0	3669.2	1112.6	3740.1	1152.0	3811.8	16
17	.2833	1037.3	3600.3	1074.6	3670.4	1113.3	3741.3	1152.7	3813.0	17
18	.3000	1037.9	3601.4	1075.2	3671.6	1113.9	3742.4	1153.3	3814.2	18
19	.3167	1038.5	3602.6	1075.9	3672.8	1114.6	3743.6	1154.0	3815.4	19
20	.3333	1039.1	3603.7	1076.6	3673.9	1115.2	3744.8	1154.7	3816.6	20
21	.3500	1039.7	3604.8	1077.2	3675.0	1115.9	3746.0	1155.4	3817.8	21
22	.3667	1040.3	3606.0	1077.8	3676.2	1116.5	3747.2	1156.0	3819.0	22
23	.3833	1041.0	3607.2	1078.5	3677.4	1117.2	3748.4	1156.7	3820.2	23
24	.4000	1041.6	3608.4	1079.1	3678.6	1117.8	3749.6	1157.4	3821.4	24
25	.4167	1042.2	3609.5	1079.8	3679.7	1118.5	3750.7	1158.1	3822.6	25
26	.4333	1042.8	3610.7	1080.4	3680.9	1119.1	3751.9	1158.7	3823.8	26
27	.4500	1043.5	3611.9	1081.1	3682.1	1119.8	3753.1	1159.4	3825.0	27
28	.4667	1044.1	3613.0	1081.7	3683.3	1120.4	3754.3	1160.1	3826.2	28
29	.4833	1044.7	3614.1	1082.4	3684.5	1121.1	3755.5	1160.8	3827.4	29
30	.5000	1045.3	3615.3	1083.0	3685.6	1121.7	3756.7	1161.4	3828.6	30
31	.5167	1045.9	3616.5	1083.6	3686.8	1122.3	3757.9	1162.1	3829.8	31
32	.5333	1046.5	3617.7	1084.2	3688.0	1123.0	3759.1	1162.8	3831.0	32
33	.5500	1047.2	3618.9	1084.9	3689.2	1123.7	3760.3	1163.5	3832.2	33
34	.5667	1047.8	3620.0	1085.5	3690.4	1124.3	3761.5	1164.1	3833.4	34
35	.5833	1048.4	3621.1	1086.2	3691.6	1125.0	3762.7	1164.8	3834.6	35
36	.6000	1049.0	3622.3	1086.8	3692.7	1125.6	3763.9	1165.5	3835.9	36
37	.6167	1049.7	3623.5	1087.5	3693.9	1126.3	3765.1	1166.2	3837.1	37
38	.6333	1050.3	3624.7	1088.1	3695.1	1126.9	3766.3	1166.8	3838.3	38
39	.6500	1050.9	3625.8	1088.8	3696.2	1127.6	3767.5	1167.5	3839.5	39
40	.6667	1051.5	3627.0	1089.4	3697.4	1128.3	3768.7	1168.2	3840.7	40
41	.6833	1052.1	3628.2	1090.0	3698.6	1129.0	3769.9	1168.9	3841.9	41
42	.7000	1052.7	3629.4	1090.6	3699.8	1129.6	3771.0	1169.5	3843.1	42
43	.7167	1053.4	3630.5	1091.3	3701.0	1130.3	3772.2	1170.2	3844.3	43
44	.7333	1054.0	3631.7	1091.9	3702.2	1130.9	3773.4	1170.9	3845.5	44
45	.7500	1054.6	3632.8	1092.6	3703.3	1131.6	3774.6	1171.6	3846.7	45
46	.7667	1055.2	3634.0	1093.2	3704.5	1132.2	3775.8	1172.2	3847.9	46
47	.7833	1055.9	3635.2	1093.9	3705.7	1132.9	3777.0	1172.9	3849.1	47
48	.8000	1056.5	3636.4	1094.5	3706.9	1133.5	3778.2	1173.6	3850.4	48
49	.8167	1057.1	3637.5	1095.2	3708.1	1134.2	3779.4	1174.3	3851.6	49
50	.8333	1057.7	3638.7	1095.8	3709.3	1134.9	3780.6	1174.9	3852.8	50
51	.8500	1058.4	3639.9	1096.4	3710.5	1135.6	3781.8	1175.6	3854.0	51
52	.8667	1059.0	3641.1	1097.0	3711.6	1136.2	3783.0	1176.3	3855.2	52
53	.8833	1059.6	3642.3	1097.7	3712.8	1136.9	3784.2	1177.0	3856.4	53
54	.9000	1060.2	3643.4	1098.3	3714.0	1137.5	3785.4	1177.6	3857.6	54
55	.9167	1060.9	3644.6	1099.0	3715.1	1138.2	3786.6	1178.3	3858.8	55
56	.9333	1061.5	3645.7	1099.6	3716.3	1138.8	3787.8	1179.0	3860.0	56
57	.9500	1062.1	3646.9	1100.3	3717.5	1139.5	3789.0	1179.7	3861.2	57
58	.9667	1062.7	3648.1	1100.9	3718.7	1140.1	3790.2	1180.3	3862.5	58
59	.9833	1063.4	3649.2	1101.6	3719.9	1140.8	3791.4	1181.0	3863.7	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	68° Ext.	68° Tan.	69° Ext.	69° Tan.	70° Ext.	70° Tan.	71° Ext.	71° Tan.	Minutes
0	.0000	1181.6	3864.9	1222.9	3938.1	1265.0	4012.1	1308.4	4087.1	0
1	.0167	1182.3	3866.1	1223.6	3939.4	1265.7	4013.4	1309.2	4088.4	1
2	.0333	1183.0	3867.3	1224.3	3940.6	1266.4	4014.6	1309.9	4089.7	2
3	.0500	1183.7	3868.5	1225.0	3941.8	1267.2	4015.9	1310.6	4091.0	3
4	.0667	1184.4	3869.7	1225.7	3943.0	1267.9	4017.1	1311.3	4092.2	4
5	.0833	1185.1	3870.9	1226.4	3944.2	1268.6	4018.4	1312.1	4093.5	5
6	.1000	1185.7	3872.2	1227.1	3945.5	1269.3	4019.6	1312.8	4094.7	6
7	.1167	1186.4	3873.4	1227.8	3946.7	1270.1	4020.8	1313.5	4096.0	7
8	.1333	1187.1	3874.6	1228.5	3947.9	1270.8	4022.1	1314.2	4097.2	8
9	.1500	1187.8	3875.8	1229.2	3949.2	1271.5	4023.4	1315.0	4098.5	9
10	.1667	1188.5	3877.0	1229.9	3950.4	1272.2	4024.6	1315.7	4099.8	10
11	.1833	1189.2	3878.2	1230.6	3951.6	1272.9	4025.8	1316.5	4101.1	11
12	.2000	1189.8	3879.5	1231.3	3952.9	1273.6	4027.1	1317.2	4102.3	12
13	.2167	1190.5	3880.7	1232.0	3954.1	1274.4	4028.4	1317.9	4103.6	13
14	.2333	1191.2	3881.9	1232.7	3955.3	1275.1	4029.6	1318.6	4104.8	14
15	.2500	1191.9	3883.1	1233.4	3956.6	1275.8	4030.8	1319.4	4106.1	15
16	.2667	1192.6	3884.3	1234.1	3957.8	1276.5	4032.1	1320.1	4107.3	16
17	.2833	1193.3	3885.6	1234.8	3959.0	1277.3	4033.4	1320.8	4108.6	17
18	.3000	1193.9	3886.8	1235.5	3960.2	1278.0	4034.6	1321.5	4109.8	18
19	.3167	1194.6	3888.0	1236.2	3961.5	1278.7	4035.9	1322.3	4111.1	19
20	.3333	1195.3	3889.2	1236.9	3962.7	1279.4	4037.1	1323.0	4112.4	20
21	.3500	1196.0	3890.4	1237.6	3964.0	1280.1	4038.4	1323.7	4113.7	21
22	.3667	1196.7	3891.6	1238.3	3965.2	1280.8	4039.6	1324.4	4114.9	22
23	.3833	1197.4	3892.9	1239.0	3966.4	1281.6	4040.9	1325.2	4116.2	23
24	.4000	1198.0	3894.1	1239.7	3967.6	1282.3	4042.1	1325.9	4117.4	24
25	.4167	1198.7	3895.3	1240.4	3968.9	1283.0	4043.4	1326.7	4118.7	25
26	.4333	1199.4	3896.5	1241.1	3970.1	1283.7	4044.6	1327.4	4119.9	26
27	.4500	1200.1	3897.7	1241.8	3971.3	1284.5	4045.9	1328.2	4121.2	27
28	.4667	1200.8	3898.9	1242.5	3972.5	1285.2	4047.1	1228.9	4122.4	28
29	.4833	1201.5	3900.2	1243.2	3973.8	1285.9	4048.4	1329.7	4123.7	29
30	.5000	1202.1	3901.4	1243.9	3975.0	1286.6	4049.6	1330.4	4125.0	30
31	.5167	1202.8	3902.6	1244.6	3976.3	1287.3	4050.9	1331.1	4126.3	31
32	.5333	1203.5	3903.8	1245.3	3977.5	1288.0	4052.1	1331.8	4127.5	32
33	.5500	1204.2	3905.0	1246.0	3978.8	1288.8	4053.4	1332.6	4128.7	33
34	.5667	1204.9	3906.3	1246.7	3980.0	1289.5	4054.6	1333.3	4130.0	34
35	.5833	1205.6	3907.5	1247.4	3981.2	1290.2	4055.9	1334.1	4131.5	35
36	.6000	1206.2	3908.7	1248.1	3982.4	1290.9	4057.1	1334.8	4132.6	36
37	.6167	1206.9	3909.9	1248.8	3983.7	1291.7	4058.4	1335.6	4133.9	37
38	.6333	1207.6	3911.2	1249.5	3984.9	1292.4	4059.6	1336.3	4135.1	38
39	.6500	1208.3	3912.4	1250.2	3986.1	1293.1	4060.9	1337.1	4136.4	39
40	.6667	1209.0	3913.6	1250.9	3987.4	1293.8	4062.1	1337.8	4137.7	40
41	.6833	1209.7	3914.9	1251.6	3988.7	1294.6	4063.4	1338.5	4139.0	41
42	.7000	1210.3	3916.1	1252.3	3989.9	1295.3	4064.6	1339.2	4140.2	42
43	.7167	1211.0	3917.3	1253.0	3991.1	1296.0	4065.9	1340.0	4141.5	43
44	.7333	1211.7	3918.5	1253.7	3992.3	1296.7	4067.1	1340.7	4142.7	44
45	.7500	1212.4	3919.8	1254.4	3993.6	1297.5	4068.4	1341.5	4144.0	45
46	.7667	1213.1	3921.0	1255.1	3994.8	1298.2	4069.6	1342.2	4145.3	46
47	.7833	1213.8	3922.2	1255.8	3996.0	1298.9	4070.9	1343.0	4146.6	47
48	.8000	1214.5	3923.4	1256.5	3997.3	1299.6	4072.1	1343.7	4147.8	48
49	.8167	1215.2	3924.7	1257.2	3998.6	1300.4	4073.4	1344.5	4149.1	49
50	.8333	1215.9	3925.9	1257.9	3999.8	1301.1	4074.6	1345.2	4150.4	50
51	.8500	1216.6	2927.1	1258.6	4001.0	1301.9	4075.9	1346.0	4151.7	51
52	.8667	1217.3	3928.3	1259.3	4002.2	1302.6	4077.1	1346.7	4152.9	52
53	.8833	1218.0	3929.6	1260.0	4003.4	1303.3	4078.4	1347.5	4154.2	53
54	.9000	1218.7	3930.8	1260.7	4004.7	1304.0	4079.6	1348.2	4155.4	54
55	.9167	1219.4	3932.0	1261.4	4006.0	1304.8	4080.9	1349.0	4156.7	55
56	.9333	1220.1	3933.2	1262.1	4007.2	1305.5	4082.1	1349.7	4158.0	56
57	9500	1220.8	3934.4	1262.8	4008.5	1306.2	4083.4	1350.5	4159.3	57
58	.9667	1221.5	3935.7	1263.5	4009.7	1306.9	4084.6	1351.2	4160.5	58
59	.9833	1222.2	3936.9	1264.3	4010.9	1307.7	4085.9	1352.0	4161.8	59

Use 100′ Chords up to 8° Curves   Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves   Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	72°		73°		74°		75°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	1352.7	4163.1	1398.1	4240.0	1444.7	4317.8	1492.5	4396.7	0
1	.0167	1353.5	4164.4	1398.9	4241.3	1445.5	4319.2	1493.3	4398.1	1
2	.0333	1354.2	4165.6	1399.6	4242.6	1446.2	4320.5	1494.1	4399.4	2
3	.0500	1355.0	4166.9	1400.4	4243.9	1447.0	4321.8	1494.9	4400.8	3
4	.0667	1355.7	4168.2	1401.2	4245.1	1447.8	4323.1	1495.7	4402.1	4
5	.0833	1356.5	4169.5	1402.0	4246.4	1448.6	4324.4	1496.5	4403.4	5
6	.1000	1357.2	4170.7	1402.7	4247.7	1449.4	4325.7	1497.3	4404.7	6
7	.1167	1358.0	4172.0	1403.5	4249.0	1450.2	4327.0	1498.2	4406.1	7
8	.1333	1358.7	4173.3	1404.2	4250.3	1451.0	4328.3	1499.0	4407.4	8
9	.1500	1359.5	4174.5	1405.0	4251.6	1451.8	4329.6	1499.8	4408.7	9
10	.1667	1360.2	4175.8	1405.8	4252.9	1452.6	4330.9	1500.6	4410.0	10
11	.1833	1361.0	4177.1	1406.6	4254.2	1453.4	4332.3	1501.4	4411.4	11
12	.2000	1361.7	4178.4	1407.3	4255.5	1454.1	4333.6	1502.2	4412.7	12
13	.2167	1362.5	4179.7	1408.1	4256.8	1454.9	4334.9	1503.0	4414.0	13
14	.2333	1363.2	4181.0	1408.8	4258.1	1455.7	4336.2	1503.8	4415.3	14
15	.2500	1364.0	4182.3	1409.6	4259.4	1456.5	4337.5	1504.6	4416.6	15
16	.2667	1364.7	4183.5	1410.4	4260.7	1457.3	4338.8	1505.4	4418.0	16
17	.2833	1365.5	4184.8	1411.2	4262.0	1458.1	4340.1	1506.2	4419.4	17
18	.3000	1366.2	4186.1	1411.9	4263.2	1458.9	4341.4	1507.0	4420.7	18
19	.3167	1367.0	4187.4	1412.7	4264.5	1459.7	4342.7	1507.9	4422.0	19
20	.3333	1367.7	4188.6	1413.5	4265.8	1460.5	4344.0	1508.7	4423.3	20
21	.3500	1368.5	4189.9	1414.3	4267.1	1461.3	4345.4	1509.5	4424.6	21
22	.3667	1369.2	4191.2	1415.1	4268.4	1462.0	4346.7	1510.3	4426.0	22
23	.3833	1370.0	4192.5	1415.9	4269.7	1462.8	4348.0	1511.2	4427.3	23
24	.4000	1370.7	4193.7	1416.6	4271.0	1463.6	4349.3	1512.0	4428.6	24
25	.4167	1371.5	4195.0	1417.4	4272.3	1464.4	4350.6	1512.8	4430.0	25
26	.4333	1372.2	4196.3	1418.2	4273.6	1465.2	4351.9	1513.6	4431.3	26
27	.4500	1373.0	4197.6	1419.0	4274.9	1466.0	4353.2	1514.5	4432.7	27
28	.4667	1373.7	4198.8	1419.7	4276.2	1466.8	4354.5	1515.3	4434.0	28
29	.4833	1374.5	4200.1	1420.5	4277.5	1467.6	4355.8	1516.1	4435.3	29
30	.5000	1375.2	4201.4	1421.3	4278.8	1468.4	4357.1	1516.9	4436.6	30
31	.5167	1376.0	4202.7	1422.1	4280.1	1469.2	4358.5	1517.7	4438.0	31
32	.5333	1376.7	4204.0	1422.9	4281.4	1469.9	4359.8	1518.5	4439.3	32
33	.5500	1377.5	4205.3	1423.7	4282.7	1470.7	4361.1	1519.4	4440.7	33
34	.5667	1378.2	4206.5	1424.4	4284.0	1471.5	4362.4	1520.2	4442.0	34
35	.5833	1379.0	4207.8	1425.2	4285.3	1472.3	4363.8	1521.0	4443.3	35
36	.6000	1379.7	4209.1	1426.0	4286.6	1473.1	4365.1	1521.8	4444.6	36
37	.6167	1380.5	4210.4	1426.8	4287.9	1473.9	4366.4	1522.7	4446.0	37
38	.6333	1381.2	4211.7	1427.5	4289.2	1474.7	4367.7	1523.5	4447.3	38
39	.6500	1382.0	4213.0	1428.3	4290.5	1475.6	4369.0	1524.3	4448.7	39
40	.6667	1382.8	4214.3	1429.1	4291.8	1476.4	4370.3	1525.1	4450.0	40
41	.6833	1383.6	4215.6	1429.9	4293.1	1477.2	4371.7	1525.9	4451.4	41
42	.7000	1384.3	4216.8	1430.7	4294.4	1478.0	4373.0	1526.7	4452.7	42
43	.7167	1385.1	4218.1	1431.5	4295.7	1478.8	4374.3	1527.6	4454.0	43
44	.7333	1385.8	4219.4	1432.2	4297.0	1479.6	4375.6	1528.4	4455.3	44
45	.7500	1386.6	4220.7	1433.0	4298.3	1480.4	4377.0	1529.2	4456.7	45
46	.7667	1387.4	4222.0	1433.8	4299.6	1481.2	4378.3	1530.0	4458.0	46
47	.7833	1388.2	4223.3	1434.6	4300.9	1482.0	4379.6	1530.9	4459.4	47
48	.8000	1388.9	4224.5	1435.3	4302.2	1482.8	4380.9	1531.7	4460.7	48
49	.8167	1389.7	4225.8	1436.1	4303.5	1483.6	4382.2	1532.5	4462.1	49
50	.8333	1390.4	4227.1	1436.9	4304.8	1484.4	4383.5	1533.3	4463.4	50
51	.8500	1391.2	4228.4	1437.7	4306.1	1485.2	4384.9	1534.1	4464.7	51
52	.8667	1392.0	4229.7	1438.5	4307.4	1486.0	4386.2	1534.9	4466.0	52
53	.8833	1392.8	4231.0	1439.3	4308.7	1486.9	4387.5	1535.8	4467.4	53
54	.9000	1393.5	4232.3	1440.0	4310.0	1487.7	4388.8	1536.6	4468.7	54
55	.9167	1394.3	4233.6	1440.8	4311.3	1488.5	4390.2	1537.4	4470.1	55
56	.9333	1395.0	4234.8	1441.6	4312.6	1489.3	4391.5	1538.2	4471.4	56
57	.9500	1395.8	4236.1	1442.4	4313.9	1490.1	4392.8	1539.1	4472.7	57
58	.9667	1396.6	4237.4	1443.1	4315.2	1490.9	4394.1	1539.9	4474.1	58
59	.9833	1397.4	4238.7	1443.9	4316.5	1491.7	4395.4	1540.7	4475.4	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	76°		77°		78°		79°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	1541.5	4476.7	1591.7	4557.8	1643.1	4640.0	1696.0	4723.4	0
1	.0167	1542.4	4478.1	1592.6	4559.2	1644.0	4641.4	1696.9	4724.8	1
2	.0333	1543.2	4479.4	1593.4	4560.5	1644.8	4642.8	1697.7	4726.2	2
3	.0500	1544.1	4480.8	1594.3	4561.9	1645.7	4644.2	1698.6	4727.6	3
4	.0667	1544.9	4482.1	1595.1	4563.3	1646.6	4645.6	1699.5	4729.0	4
5	.0833	1545.7	4483.5	1596.0	4564.7	1647.5	4647.0	1700.4	4730.4	5
6	.1000	1546.5	4484.8	1596.8	4566.0	1648.3	4648.3	1701.3	4731.8	6
7	.1167	1547.4	4486.2	1597.7	4567.4	1649.2	4649.7	1702.2	4733.3	7
8	.1333	1548.2	4487.5	1598.5	4568.7	1650.1	4651.1	1703.1	4734.7	8
9	.1500	1549.1	4488.9	1599.4	4570.1	1651.0	4652.5	1704.0	4736.1	9
10	.1667	1549.9	4490.2	1600.2	4571.5	1651.8	4653.9	1704.9	4737.5	10
11	.1833	1550.7	4491.6	1601.1	4572.9	1652.7	4655.3	1705.8	4738.9	11
12	.2000	1551.5	4492.9	1601.9	4574.2	1653.6	4656.7	1706.6	4740.3	12
13	.2167	1552.4	4494.3	1602.8	4575.6	1654.5	4658.1	1707.5	4741.7	13
14	.2333	1553.2	4495.6	1603.6	4576.9	1655.3	4659.4	1708.4	4743.1	14
15	.2500	1554.1	4497.0	1604.5	4578.3	1656.2	4660.8	1709.3	4744.5	15
16	.2667	1554.9	4498.3	1605.3	4579.7	1657.1	4662.2	1710.2	4745.9	16
17	.2833	1555.7	4499.7	1606.2	4581.1	1658.0	4663.6	1711.1	4747.3	17
18	.3000	1556.5	4501.0	1607.0	4582.4	1658.8	4665.0	1712.0	4748.7	18
19	.3167	1557.4	4502.4	1607.9	4583.8	1659.7	4666.4	1712.9	4750.1	19
20	.3333	1558.2	4503.7	1608.7	4585.1	1660.6	4667.7	1713.8	4751.5	20
21	.3500	1559.1	4505.0	1609.6	4586.5	1661.5	4669.1	1714.7	4752.9	21
22	.3667	1559.9	4506.3	1610.4	4587.9	1662.3	4670.5	1715.6	4754.3	22
23	.3833	1560.7	4507.7	1611.3	4589.3	1663.2	4671.9	1716.5	4755.7	23
24	.4000	1561.5	4509.0	1612.1	4590.6	1664.1	4673.3	1717.4	4757.1	24
25	.4167	1562.4	4510.4	1613.0	4592.0	1665.0	4674.7	1718.3	4758.6	25
26	.4333	1563.2	4511.7	1613.8	4593.3	1665.8	4676.0	1719.2	4760.0	26
27	.4500	1564.1	4513.1	1614.7	4594.7	1666.7	4677.4	1720.1	4761.4	27
28	.4667	1564.9	4514.4	1615.5	4596.0	1667.6	4678.8	1721.0	4762.8	28
29	.4833	1565.7	4515.8	1616.4	4597.4	1668.5	4680.2	1721.9	4764.2	29
30	.5000	1566.5	4517.1	1617.3	4598.8	1669.3	4681.6	1722.8	4765.6	30
31	.5167	1567.4	4518.5	1618.2	4600.2	1670.2	4683.0	1723.7	4767.0	31
32	.5333	1568.2	4519.8	1619.0	4601.5	1671.1	4684.4	1724.6	4768.4	32
33	.5500	1569.1	4521.1	1619.9	4602.9	1672.0	4685.8	1725.5	4769.8	33
34	.5667	1569.9	4522.5	1620.7	4604.3	1672.8	4687.2	1726.4	4771.2	34
35	.5833	1570.7	4523.9	1621.6	4605.7	1673.7	4688.6	1727.3	4772.7	35
36	.6000	1571.5	4525.3	1622.4	4607.0	1674.6	4689.9	1728.2	4774.1	36
37	.6167	1572.4	4526.7	1623.3	4608.4	1675.5	4691.3	1729.1	4775.5	37
38	.6333	1573.2	4528.0	1624.1	4609.8	1676.3	4692.7	1730.0	4776.9	38
39	.6500	1574.0	4529.4	1625.0	4611.2	1677.3	4694.1	1731.0	4778.3	39
40	.6667	1574.8	4530.7	1625.9	4612.5	1678.2	4695.5	1731.9	4779.7	40
41	.6833	1575.6	4532.1	1626.8	4613.9	1679.1	4696.9	1732.8	4781.1	41
42	.7000	1576.4	4533.4	1627.6	4615.3	1679.9	4698.3	1733.7	4782.6	42
43	.7167	1577.3	4534.8	1628.5	4616.7	1680.8	4699.7	1734.6	4784.0	43
44	.7333	1578.1	4536.1	1629.3	4618.0	1681.7	4701.1	1735.5	4785.4	44
45	.7500	1579.0	4537.5	1630.2	4619.4	1682.6	4702.5	1736.4	4786.8	45
46	.7667	1579.8	4538.8	1631.0	4620.8	1683.5	4703.9	1737.3	4788.2	46
47	.7833	1580.7	4540.2	1631.9	4622.2	1684.4	4705.3	1738.2	4789.6	47
48	.8000	1581.5	4541.5	1632.7	4623.5	1685.3	4706.7	1739.1	4791.0	48
49	.8167	1582.4	4542.9	1633.6	4624.9	1686.2	4708.1	1740.0	4792.5	49
50	.8333	1583.2	4544.2	1634.5	4626.3	1687.1	4709.5	1740.9	4793.9	50
51	.8500	1584.1	4545.6	1635.4	4627.7	1688.0	4710.9	1741.8	4795.3	51
52	.8667	1584.9	4547.0	1636.2	4629.0	1688.8	4712.2	1742.7	4796.7	52
53	.8833	1585.8	4548.4	1637.1	4630.4	1689.7	4713.6	1743.6	4798.1	53
54	.9000	1586.6	4549.7	1637.9	4631.8	1690.6	4715.0	1744.5	4799.5	54
55	.9167	1587.5	4551.1	1638.8	4633.2	1691.5	4716.4	1745.4	4801.0	55
56	.9333	1588.3	4552.4	1639.6	4634.5	1692.4	4717.8	1746.3	4802.4	56
57	.9500	1589.2	4553.8	1640.5	4635.9	1693.3	4719.2	1747.2	4803.8	57
58	.9667	1590.0	4555.1	1641.3	4637.3	1694.2	4720.6	1748.1	4805.2	58
59	.9833	1590.9	4556.5	1642.2	4638.7	1695.1	4722 0	1749.1	4806.6	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	80° Ext.	80° Tan.	81° Ext.	81° Tan.	82° Ext.	82° Tan.	83° Ext.	83° Tan.	Minutes
0	.0000	1750.0	4808.0	1805.5	4893.9	1862.3	4981.0	1920.6	5069.4	0
1	.0167	1750.9	4809.5	1806.4	4895.4	1863.3	4982.5	1921.6	5070.9	1
2	.0333	1751.8	4810.9	1807.3	4896.8	1864.2	4983.9	1922.6	5072.4	2
3	.0500	1752.8	4812.3	1808.3	4898.3	1865.2	4985.4	1923.6	5073.9	3
4	.0667	1753.7	4813.7	1809.2	4899.7	1866.1	4986.8	1924.6	5075.4	4
5	.0833	1754.6	4815.2	1810.2	4901.2	1867.1	4988.3	1925.6	5076.9	5
6	.1000	1755.5	4816.6	1811.1	4902.6	1868.1	4989.8	1926.5	5078.4	6
7	.1167	1756.5	4818.0	1812.1	4904.0	1869.1	4991.3	1927.5	5079.9	7
8	.1333	1757.4	4819.4	1813.0	4905.4	1870.0	4992.7	1928.5	5081.4	8
9	.1500	1758.3	4820.9	1814.0	4906.9	1871.0	4994.2	1929.5	5082.9	9
10	.1667	1759.2	4822.3	1814.9	4908.3	1871.9	4995.7	1930.5	5084.4	10
11	.1833	1760.1	4823.7	1815.9	4909.8	1872.9	4997.2	1931.5	5085.9	11
12	.2000	1761.0	4825.1	1816.8	4911.2	1873.9	4998.6	1932.4	5087.3	12
13	.2167	1762.0	4826.6	1817.7	4912.7	1874.9	5000.1	1933.4	5088.8	13
14	.2333	1762.9	4828.0	1818.6	4914.1	1875.8	5001.5	1934.4	5090.3	14
15	.2500	1763.8	4829.4	1819.6	4915.5	1876.8	5003.0	1935.4	5091.8	15
16	.2667	1764.7	4830.8	1820.5	4917.0	1877.7	5004.5	1936.4	5093.3	16
17	.2833	1765.7	4832.3	1821.5	4918.5	1878.7	5006.0	1937.4	5094.8	17
18	.3000	1766.6	4833.7	1822.4	4919.9	1879.7	5007.4	1938.4	5096.3	18
19	.3167	1767.5	4835.1	1823.3	4921.4	1880.7	5008.9	1939.4	5097.8	19
20	.3333	1768.4	4836.5	1824.2	4922.8	1881.6	5010.3	1940.4	5099.3	20
21	.3500	1769.3	4838.0	1825.2	4924.3	1882.6	5011.8	1941.4	5100.8	21
22	.3667	1770.2	4839.4	1826.1	4925.7	1883.5	5013.3	1942.4	5102.3	22
23	.3833	1771.2	4840.8	1827.1	4927.2	1884.5	5014.8	1943.4	5103.8	23
24	.4000	1772.1	4842.2	1828.0	4928.6	1885.5	5016.2	1944.4	5105.2	24
25	.4167	1773.0	4843.7	1829.0	4930.1	1886.5	5017.7	1945.4	5106.7	25
26	.4333	1773.9	4845.1	1829.9	4931.5	1887.4	5019.2	1946.4	5108.2	26
27	.4500	1774.9	4846.5	1830.9	4933.0	1888.4	5020.7	1947.4	5109.7	27
28	.4667	1775.8	4847 9	1831.8	4934.4	1889.3	5022.1	1948.4	5111.2	28
29	.4833	1776.7	4849.4	1832.8	4935.8	1890.3	5023.6	1949.4	5112.7	29
30	.5000	1777.6	4850.8	1833.7	4937.2	1891.3	5025.0	1950.4	5114.2	30
31	.5167	1778.5	4852.3	1834.7	4938.7	1892.3	5026.5	1951.4	5115.7	31
32	.5333	1779.4	4853.7	1835.6	4940.2	1893.2	5028.0	1952.4	5117.2	32
33	.5500	1780.4	4855.1	1836.6	4941.7	1894.2	5029.5	1953.4	5118.7	33
34	.5667	1781.3	4856.5	1837.5	4943.1	1895.1	5031.0	1954.4	5120.2	34
35	.5833	1782.2	4858.0	1838.5	4944.6	1896.1	5032.5	1955.4	5121.7	35
36	.6000	1783.1	4859.4	1839.4	4946.0	1897.1	5033.9	1956.4	5123.2	36
37	.6167	1784.1	4860.9	1840.4	4947.5	1898.1	5035.4	1957.4	5124.7	37
38	.6333	1785.0	4862.3	1841.3	4948.9	1899.0	5036.9	1958.4	5126.2	38
39	.6500	1785.9	4863.7	1842.3	4950.4	1900.0	5038.4	1959.4	5127.7	39
40	.6667	1786.8	4865.1	1843.2	4951.8	1901.0	5039.8	1960.4	5129.2	40
41	.6833	1787.7	4866.6	1844.2	4953.3	1902.0	5041.3	1961.4	5130.7	41
42	.7000	1788.6	4868.0	1845.1	4954.7	1902.9	5042.8	1962.4	5132.2	42
43	.7167	1789.6	4869.5	1846.1	4956.2	1903.9	5044.3	1963.4	5133.7	43
44	.7333	1790.5	4870.9	1847.0	4957.6	1904.9	5045.8	1964.4	5135.2	44
45	.7500	1791.5	4872.4	1848.0	4959.1	1905.9	5047.3	1965.4	5136.7	45
46	.7667	1792.4	4873.8	1848.9	4960.6	1906.9	5048.7	1966.4	5138.2	46
47	.7833	1793.4	4875.2	1849.9	4962.1	1907.9	5050.2	1967.4	5139.7	47
48	.8000	1794.3	4876.6	1850.8	4963.5	1908.8	5051.7	1968.4	5141.2	48
49	.8167	1795.3	4878.1	1851.8	4965.0	1909.8	5053.2	1969.4	5142.8	49
50	.8333	1796.2	4879.5	1852.7	4966.4	1910.8	5054.6	1970.4	5144.3	50
51	.8500	1797.1	4880.9	1853.7	4967.9	1911.8	5056.1	1971.4	5145.8	51
52	.8667	1798.0	4882.4	1854.6	4969.3	1912.8	5057.6	1972.4	5147.3	52
53	.8833	1799.0	4883.9	1855.6	4970.8	1913 8	5059.1	1973.4	5148.8	53
54	.9000	1799.9	4885.3	1856.5	4972.2	1914.7	5060.6	1974.4	5150.3	54
55	.9167	1800.9	4886.7	1857.5	4973.7	1915.7	5062.1	1975.4	5151.8	55
56	.9333	1801.8	4888.1	1858.4	4975.1	1916.7	5063.5	1976.4	5153.3	56
57	.9500	1802.8	4889.6	1859.4	4976.6	1917.7	5065.0	1977.4	5154.8	57
58	.9667	1803.7	4891.0	1860.3	4978.0	1918.7	5066.5	1978.4	5156.3	58
59	.9833	1804.6	4892.5	1861.3	4979.5	1919.7	5068.0	1979.4	5157.8	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	84°		85°		86°		87°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	1980.5	5159.3	2041.8	5250.6	2104.8	5343.3	2169.5	5437.5	0
1	.0167	1981.5	5160.8	2042.9	5252.1	2105.9	5344.9	2170.6	5439.1	1
2	.0333	1982.5	5162.3	2043.9	5253.6	2106.9	5346.4	2171.6	5440.7	2
3	.0500	1983.5	5163.8	2045.0	5255.2	2108.0	5348.0	2172.7	5442.3	3
4	.0667	1984.5	5165.3	2046.0	5256.7	2109.1	5349.5	2173.8	5443.9	4
5	.0833	1985.6	5166.9	2047.0	5258.3	2110.1	5351.1	2174.9	5445.5	5
6	.1000	1986.6	5168.4	2048.0	5259.8	2111.2	5352.7	2176.0	5447.1	6
7	.1167	1987.6	5169.9	2049.1	5261.4	2112.3	5354.3	2177.1	5448.7	7
8	.1333	1988.6	5171.4	2050.1	5262.9	2113.4	5355.8	2178.2	5450.3	8
9	.1500	1989.6	5172.9	2051.2	5264.5	2114.5	5357.4	2179.3	5451.9	9
10	.1667	1990.6	5174.4	2052.2	5266.0	2115.5	5358.9	2180.4	5453.4	10
11	.1833	1991.7	5175.9	2053.2	5267.5	2116.6	5360.5	2181.5	5455.0	11
12	.2000	1992.7	5177.5	2054.2	5269.0	2117.6	5362.0	2182.5	5456.6	12
13	.2167	1993.7	5179.0	2055.3	5270.6	2118.7	5363.6	2183.6	5458.2	13
14	.2333	1994.7	5180.5	2056.3	5272.1	2119.8	5365.2	2184.7	5459.8	14
15	.2500	1995.7	5182.0	2057.4	5273.7	2120.9	5366.8	2185.8	5461.4	15
16	.2667	1996.7	5183.5	2058.4	5275.2	2121.9	5368.3	2186.9	5463.0	16
17	.2833	1997.8	5185.0	2059.5	5276.8	2123.0	5369.9	2188.0	5464.6	17
18	.3000	1998.8	5186.6	2060.5	5278.3	2124.1	5371.4	2189.1	5466.2	18
19	.3167	1999.8	5188.0	2061.6	5279.9	2125.2	5373.0	2190.2	5467.8	19
20	.3333	2000.8	5189.6	2062.6	5281.4	2126.2	5374.6	2191.3	5469.4	20
21	.3500	2001.8	5191.0	2063.7	5282.9	2127.3	5376.2	2192.4	5471.0	21
22	.3667	2002.8	5192.6	2064.7	5284.4	2128.3	5377.7	2193.5	5472.5	22
23	.3833	2003.9	5194.0	2065.8	5286.0	2129.4	5379.3	2194.6	5474.1	23
24	.4000	2004.9	5195.6	2066.8	5287.5	2130.5	5380.8	2195.7	5475.7	24
25	.4167	2005.9	5197.2	2067.9	5289.1	2131.6	5382.4	2196.8	5477.3	25
26	.4333	2006.9	5198.7	2068.9	5290.6	2132.6	5383.9	2197.9	5478.9	26
27	.4500	2007.9	5200.2	2070.0	5292.2	2133.7	5385.5	2199.0	5480.5	27
28	.4667	2008.9	5201.7	2071.0	5293.7	2134.8	5387.1	2200.1	5482.1	28
29	.4833	2010.0	5203.2	2072.1	5295.2	2135.9	5388.7	2201.2	5483.7	29
30	.5000	2011.0	5204.7	2073.1	5296.7	2136.9	5390.2	2202.3	5485.3	30
31	.5167	2012.0	5206.3	2074.2	5298.3	2138.0	5391.8	2203.4	5486.9	31
32	.5333	2013.0	5207.8	2075.2	5299.8	2139.0	5393.4	2204.5	5488.5	32
33	.5500	2014.0	5209.3	2076.3	5301.4	2140.1	5395.0	2205.6	5490.1	33
34	.5667	2015.0	5210.8	2077.3	5302.9	2141.2	5396.5	2206.8	5491.7	34
35	.5833	2016.0	5212.4	2078.4	5304.5	2142.3	5398.1	2207.9	5493.3	35
36	.6000	2017.0	5213.9	2079.4	5306.1	2143.3	5399.7	2209.0	5494.9	36
37	.6167	2018.0	5215.4	2080.5	5307.7	2144.4	5401.3	2210.1	5496.5	37
38	.6333	2019.1	5216.9	2081.5	5309.2	2145.5	5402.8	2211.2	5498.1	38
39	.6500	2020.1	5218.4	2082.6	5310.8	2146.6	5404.4	2212.3	5499.7	39
40	.6667	2021.2	5220.0	2083.7	5312.3	2147.7	5406.0	2213.4	5501.3	40
41	.6833	2022.2	5221.6	2084.8	5313.9	2148.8	5407.6	2214.5	5502.9	41
42	.7000	2023.2	5223.1	2085.8	5315.4	2149.8	5409.1	2215.6	5504.5	42
43	.7167	2024.3	5224.6	2086.9	5317.0	2150.9	5410.7	2216.7	5506.1	43
44	.7333	2025.3	5226.1	2087.9	5318.5	2152.0	5412.3	2217.8	5507.7	44
45	.7500	2026.4	5227.7	2089.0	5320.1	2153.1	5413.9	2218.9	5509.3	45
46	.7667	2027.4	5229.2	2090.0	5321.6	2154.2	5415.4	2220.0	5510.9	46
47	.7833	2028.4	5230.7	2091.1	5323.2	2155.3	5417.0	2221.2	5512.5	47
48	.8000	2029.4	5232.2	2092.1	5324.7	2156.4	5418.6	2222.3	5514.1	48
49	.8167	2030.5	5233.8	2093.2	5326.3	2157.5	5420.2	2223.4	5515.7	49
50	.8333	2031.5	5235.3	2094.2	5327.8	2158.6	5421.8	2224.5	5517.3	50
51	.8500	2032.6	5236.8	2095.3	5329.4	2159.7	5423.4	2225.6	5518.9	51
52	.8667	2033.6	5238.3	2096.3	5330.9	2160.7	5424.9	2226.7	5520.5	52
53	.8833	2034.6	5239.9	2097.4	5332.5	2161.8	5426.5	2227.9	5522.1	53
54	.9000	2035.6	5241.4	2098.4	5334.0	2162.9	5428.1	2228.9	5523.7	54
55	.9167	2036.7	5243.0	2099.5	5335.6	2164.0	5429.7	2230.0	5525.3	55
56	.9333	2037.7	5244.5	2100.6	5337.1	2165.1	5431.2	2231.1	5526.9	56
57	.9500	2038.7	5246.0	2101.7	5338.7	2166.2	5432.8	2232.2	5528.5	57
58	.9667	2039.8	5247.5	2102.7	5340.2	2167.3	5434.4	2233.3	5530.1	58
59	.9833	2040.8	5249.1	2103.8	5341.8	2168.4	5436.0	2234.5	5531.7	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	88°		89°		90°		91°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	2235.6	5533.3	2303.6	5630.8	2373.4	5730.0	2445.1	5830.9	0
1	.0167	2236.7	5535.0	2304.7	5632.5	2374.6	5731.7	2446.3	5832.6	1
2	.0333	2237.8	5536.6	2305.6	5634.1	2375.8	5733.3	2447.5	5834.3	2
3	.0500	2238.9	5538.2	2307.2	5635.8	2377.0	5735.0	2448.8	5836.0	3
4	.0667	2240.1	5539.8	2308.1	5637.4	2378.2	5736.7	2450.0	5837.7	4
5	.0833	2241.2	5541.5	2309.4	5639.1	2379.4	5738.4	2451.2	5839.4	5
6	.1000	2242.3	5543.1	2310.5	5640.7	2380.5	5740.0	2452.4	5841.1	6
7	.1167	2243.5	5544.7	2311.6	5642.4	2381.7	5741.7	2453.6	5842.8	7
8	.1333	2244.6	5546.3	2312.8	5644.0	2382.9	5743.4	2454.8	5844.5	8
9	.1500	2245.7	5547.9	2314.0	5645.7	2384.1	5745.1	2456.0	5846.2	9
10	.1667	2246.8	5549.5	2315.1	5647.3	2385.3	5746.7	2457.2	5847.9	10
11	.1833	2248.0	5551.2	2316.3	5649.0	2386.4	5748.4	2458.5	5849.6	11
12	.2000	2249.1	5552.8	2317.4	5650.6	2387.6	5750.0	2459.7	5851.3	12
13	.2167	2250.2	5554.4	2318.6	5652.3	2388.8	5751.7	2460.9	5853.0	13
14	.2333	2251.3	5556.0	2319.7	5653.9	2390.0	5753.4	2462.1	5854.7	14
15	.2500	2252.5	5557.6	2320.9	5655.5	2391.2	5755.1	2463.3	5856.4	15
16	.2667	2253.6	5559.2	2322.0	5657.1	2392.4	5756.7	2464.5	5858.1	16
17	.2833	2254.7	5560.9	2323.2	5658.8	2393.5	5758.4	2465.8	5859.8	17
18	.3000	2255.8	5562.5	2324.3	5660.4	2394.7	5760.1	2467.0	5861.5	18
19	.3167	2257.0	5564.1	2325.6	5662.1	2395.9	5761.8	2468.2	5863.2	19
20	.3333	2258.1	5565.7	2326.7	5663.7	2397.1	5763.4	2469.4	5864.9	20
21	.3500	2259.3	5567.3	2327.9	5665.4	2398.3	5765.1	2470.6	5866.6	21
22	.3667	2260.4	5568.9	2329.0	5667.0	2399.5	5766.8	2471.9	5868.3	22
23	.3833	2261.5	5570.6	2330.1	5668.7	2400.7	5768.5	2473.1	5870.1	23
24	.4000	2262.7	5572.2	2331.3	5670.3	2401.9	5770.1	2474.3	5871.8	24
25	.4167	2263.8	5573.8	2332.5	5672.0	2403.1	5771.8	2475.5	5873.5	25
26	.4333	2264.9	5575.4	2333.7	5673.6	2404.3	5773.5	2476.7	5875.2	26
27	.4500	2266.0	5577.0	2334.8	5675.3	2405.5	5775.2	2478.0	5876.9	27
28	.4667	2267.2	5578.6	2336.0	5676.9	2406.6	5776.9	2479.2	5878.6	28
29	.4833	2268.4	5580.3	2337.1	5678.6	2407.8	5778.6	2480.4	5880.3	29
30	.5000	2269.5	5581.9	2338.3	5680.2	2409.0	5780.2	2481.6	5882.0	30
31	.5167	2270.6	5583.5	2339.5	5681.9	2410.2	5781.9	2482.9	5883.7	31
32	.5333	2271.7	5585.1	2340.7	5683.5	2411.4	5783.6	2484.1	5885.4	32
33	.5500	2272.8	5586.8	2341.9	5685.2	2412.6	5785.3	2485.3	5887.2	33
34	.5667	2273.9	5588.4	2343.0	5686.8	2413.8	5787.0	2486.5	5888.9	34
35	.5833	2275.1	5590.1	2344.1	5688.5	2415.0	5788.7	2487.8	5890.6	35
36	.6000	2276.2	5591.7	2345.3	5690.2	2416.2	5790.3	2489.0	5892.3	36
37	.6167	2277.3	5593.3	2346.5	5691.9	2417.4	5792.0	2490.3	5894.0	37
38	.6333	2278.5	5594.9	2347.7	5693.5	2418.6	5793.7	2491.5	5895.7	38
39	.6500	2279.7	5596.6	2348.9	5695.2	2419.8	5795.4	2492.7	5897.5	39
40	.6667	2280.8	5598.2	2350.0	5696.8	2421.0	5797.1	2493.9	5899.2	40
41	.6833	2281.9	5599.8	2351.2	5698.5	2422.2	5798.8	2495.2	5900.9	41
42	.7000	2283.0	5601.4	2352.3	5700.1	2423.4	5800.4	2496.4	5902.6	42
43	.7167	2284.1	5603.1	2353.5	5701.8	2424.6	5802.1	2497.7	5904.3	43
44	.7333	2285.3	5604.7	2354.7	5703.4	2425.8	5803.8	2498.9	5906.0	44
45	.7500	2286.5	5606.4	2355.8	5705.1	2427.0	5805.5	2500.1	5907.7	45
46	.7667	2287.6	5608.0	2357.0	5706.8	2428.2	5807.2	2501.3	5909.4	46
47	.7833	2288.7	5609.6	2358.1	5708.5	2429.4	5808.9	2502.6	5911.2	47
48	.8000	2289.9	5611.2	2359.3	5710.1	2430.6	5810.6	2503.8	5912.9	48
49	.8167	2291.1	5612.9	2360.5	5711.8	2431.8	5812.3	2505.1	5914.6	49
50	.8333	2292.2	5614.5	2361.7	5713.4	2433.0	5814.0	2506.3	5916.3	50
51	.8500	2293.3	5616.2	2362.9	5715.1	2434.2	5815.7	2507.5	5918.1	51
52	.8667	2294.4	5617.8	2364.0	5716.7	2435.4	5817.3	2508.7	5919.8	52
53	.8833	2295.6	5619.4	2365.1	5718.4	2436.6	5819.0	2510.0	5921.5	53
54	.9000	2296.7	5621.0	2366.3	5720.0	2437.9	5820.7	2511.2	5923.2	54
55	.9167	2297.9	5622.7	2367.5	5721.7	2439.1	5822.4	2512.5	5925.0	55
56	.9333	2299.0	5624.3	2368.7	5723.4	2440.3	5824.1	2513.7	5926.7	56
57	.9500	2300.2	5625.9	2369.9	5725.1	2441.5	5825.8	2515.0	5928.4	57
58	.9667	2301.3	5627.5	2371.0	5726.7	2442.7	5827.5	2516.2	5930.1	58
59	.9833	2302.4	5629.2	2372.2	5728.4	2443.9	5829.2	2517.5	5931.9	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	92°		93°		94°		95°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	2518.7	5933.6	2594.2	6038.2	2671.8	6144.7	2751.5	6253.2	0
1	.0167	2520.0	5935.3	2595.5	6040.0	2673.1	6146.5	2752.9	6255.1	1
2	.0333	2521.2	5937.0	2596.8	6041.7	2674.4	6148.3	2754.2	6256.9	2
3	.0500	2522.4	5938.8	2598.1	6043.5	2675.7	6150.1	2755.6	6258.7	3
4	.0667	2523.6	5940.5	2599.3	6045.2	2677.0	6151.9	2756.9	6260.5	4
5	.0833	2524.9	5942.3	2600.6	6047.0	2678.4	6153.7	2758.3	6262.4	5
6	.1000	2526.1	5944.0	2601.9	6048.7	2679.7	6155.4	2759.6	6264.2	6
7	.1167	2527.4	5945.7	2603.2	6050.5	2681.0	6157.2	2761.0	6266.0	7
8	.1333	2528.6	5947.4	2604.4	6052.2	2682.3	6159.0	2762.3	6267.8	8
9	.1500	2529.9	5949.2	2605.7	6054.0	2683.6	6160.8	2763.7	6269.7	9
10	.1667	2531.1	5950.9	2607.0	6055.8	2684.9	6162.6	2765.0	6271.5	10
11	.1833	2532.4	5952.7	2608.3	6057.5	2686.3	6164.4	2766.4	6273.4	11
12	.2000	2533.6	5954.4	2609.6	6059.3	2687.6	6166.2	2767.7	6275.2	12
13	.2167	2534.9	5956.1	2610.9	6061.1	2688.9	6168.0	2769.1	6277.0	13
14	.2333	2536.1	5957.8	2612.1	6062.8	2690.2	6169.8	2770.4	6278.8	14
15	.2500	2537.4	5959.6	2613.4	6064.6	2691.5	6171.6	2771.8	6280.7	15
16	.2667	2538.6	5961.3	2614.7	6066.4	2692.8	6173.4	2773.1	6282.5	16
17	.2833	2539.9	5963.1	2616.0	6068.2	2694.2	6175.2	2774.5	6284.4	17
18	.3000	2541.1	5964.8	2617.3	6069.9	2695.6	6177.0	2775.8	6286.2	18
19	.3167	2542.4	5966.5	2618.6	6071.7	2696.9	6178.8	2777.2	6288.0	19
20	.3333	2543.6	5968.2	2619.8	6073.4	2698.1	6180.6	2778.5	6289.8	20
21	.3500	2544.9	5970.0	2621.1	6075.2	2699.5	6182.4	2779.9	6291.7	21
22	.3667	2546.1	5971.7	2622.4	6077.0	2700.8	6184.2	2781.2	6293.5	22
23	.3833	2547.4	5973.5	2623.7	6078.8	2702.1	6186.0	2782.6	6295.4	23
24	.4000	2548.6	5975.2	2625.0	6080.5	2703.4	6187.8	2784.0	6297.2	24
25	.4167	2549.9	5977.0	2626.3	6082.3	2704.8	6189.7	2785.4	6299.1	25
26	.4333	2551.2	5978.7	2627.6	6084.1	2706.1	6191.5	2786.7	6300.9	26
27	.4500	2552.5	5980.5	2628.9	6085.9	2707.4	6193.3	2788.1	6302.7	27
28	.4667	2553.7	5982.2	2630.2	6087.6	2708.7	6195.1	2789.4	6304.6	28
29	.4833	2555.0	5983.9	2631.5	6089.4	2710.1	6196.9	2790.8	6306.4	29
30	.5000	2556.2	5985.6	2632.7	6091.2	2711.4	6198.7	2792.1	6308.2	30
31	.5167	2557.5	5987.4	2634.0	6093.0	2712.7	6200.5	2793.5	6310.1	31
32	.5333	2558.7	5989.1	2635.3	6094.7	2714.0	6202.3	2794.9	6311.9	32
33	.5500	2560.0	5990.9	2636.6	6096.5	2715.4	6204.1	2796.3	6313.8	33
34	.5667	2561.2	5992.6	2637.9	6098.3	2716.7	6205.9	2797.6	6315.6	34
35	.5833	2562.5	5994.4	2639.2	6100.1	2718.0	6207.7	2799.0	6317.5	35
36	.6000	2563.8	5996.1	2640.5	6101.8	2719.3	6209.5	2800.3	6319.3	36
37	.6167	2565.1	5997.9	2641.8	6103.6	2720.7	6211.4	2801.7	6321.2	37
38	.6333	2566.3	5999.6	2643.1	6105.4	2722.0	6213.2	2803.1	6323.0	38
39	.6500	2567.6	6001.4	2644.4	6107.2	2723.4	6215.0	2804.5	6324.9	39
40	.6667	2568.8	6003.1	2645.7	6109.0	2724.7	6216.8	2805.8	6326.7	40
41	.6833	2570.1	6004.9	2647.0	6110.8	2726.0	6218.6	2807.2	6328.6	41
42	.7000	2571.3	6006.6	2648.3	6112.5	2727.3	6220.4	2808.6	6330.4	42
43	.7167	2572.6	6008.4	2649.6	6114.3	2728.7	6222.3	2810.0	6332.3	43
44	.7333	2573.9	6010.1	2650.9	6116.1	2730.0	6224.1	2811.3	6334.1	44
45	.7500	2575.2	6011.9	2652.2	6117.9	2731.4	6225.9	2812.7	6336.0	45
46	.7667	2576.4	6013.6	2653.5	6119.7	2732.7	6227.7	2814.1	6337.8	46
47	.7833	2577.7	6015.4	2654.8	6121.5	2734.1	6229.5	2815.5	6339.7	47
48	.8000	2578.9	6017.1	2656.1	6123.2	2735.4	6231.3	2816.8	6341.5	48
49	.8167	2580.2	6018.9	2657.4	6125.0	2736.7	6233.2	2818.2	6343.4	49
50	.8333	2581.5	6020.6	2658.7	6126.8	2738.0	6235.0	2819.6	6345.2	50
51	.8500	2582.8	6022.4	2660.0	6128.6	2739.4	6236.8	2821.0	6347.1	51
52	.8667	2584.0	6024.1	2661.3	6130.4	2740.7	6238.6	2822.3	6349.0	52
53	.8833	2585.3	6025.9	2662.6	6132.2	2742.1	6240.5	2823.7	6350.9	53
54	.9000	2586.6	6027.6	2663.9	6133.9	2743.4	6242.3	2825.1	6352.7	54
55	.9167	2587.9	6029.4	2665.3	6135.7	2744.8	6244.2	2826.5	6354.6	55
56	.9333	2589.1	6031.1	2666.6	6137.5	2746.1	6246.0	2827.8	6356.4	56
57	.9500	2590.4	6032.9	2667.9	6139.3	2747.5	6247.8	2829.2	6358.3	57
58	.9667	2591.7	6034.6	2669.2	6141.1	2748.8	6249.6	2830.6	6360.1	58
59	.9833	2593.0	6036.4	2670.5	6142.9	2750.2	6251.4	2832.0	6362.0	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	96°		97°		98°		99°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	2833.4	6363.8	2917.5	6476.6	3004.0	6591.6	3092.9	6709.0	0
1	.0167	2834.8	6365.7	2918.9	6478.5	3005.5	6593.6	3094.4	6711.0	1
2	.0333	2836.1	6367.5	2920.3	6480.4	3006.9	6595.5	3095.9	6712.9	2
3	.0500	2837.5	6369.4	2921.8	6482.3	3008.4	6597.5	3097.4	6714.9	3
4	.0667	2838.9	6371.3	2923.2	6484.2	3009.8	6599.4	3098.9	6716.9	4
5	.0833	2840.3	6373.2	2924.6	6486.1	3011.3	6601.3	3100.4	6718.9	5
6	.1000	2841.7	6375.0	2926.0	6488.0	3012.8	6603.2	3101.9	6720.8	6
7	.1167	2843.1	6376.9	2927.5	6489.9	3014.3	6605.2	3103.4	6722.8	7
8	.1333	2844.5	6378.7	2928.9	6491.8	3015.7	6607.1	3104.9	6724.8	8
9	.1500	2845.9	6380.6	2930.3	6493.7	3017.2	6609.1	3106.4	6726.8	9
10	.1667	2847.2	6382.5	2931.7	6495.6	3018.6	6611.0	3107.9	6728.8	10
11	.1833	2848.6	6384.4	2933.2	6497.5	3020.1	6613.0	3109.5	6730.8	11
12	.2000	2850.0	6386.2	2934.6	6499.4	3021.6	6614.9	3111.0	6732.7	12
13	.2167	2851.4	6388.1	2936.1	6501.3	3023.1	6616.9	3112.5	6734.7	13
14	.2333	2852.8	6389.9	2937.5	6503.2	3024.5	6618.8	3114.0	6736.7	14
15	.2500	2854.2	6391.8	2938.9	6505.2	3026.0	6620.8	3115.5	6738.7	15
16	.2667	2855.6	6393.7	2940.3	6507.1	3027.5	6622.7	3117.0	6740.7	16
17	.2833	2857.0	6395.6	2941.8	6509.0	3029.0	6624.7	3118.5	6742.7	17
18	.3000	2858.4	6397.4	2943.2	6510.9	3030.4	6626.6	3120.0	6744.6	18
19	.3167	2859.8	6399.3	2944.7	6512.8	3031.9	6628.6	3121.5	6746.6	19
20	.3333	2861.2	6401.2	2946.1	6514.7	3033.3	6630.5	3123.1	6748.6	20
21	.3500	2862.6	6403.1	2947.5	6516.6	3034.8	6632.5	3124.6	6750.6	21
22	.3667	2864.0	6404.9	2948.9	6518.5	3036.3	6634.4	3126.1	6752.6	22
23	.3833	2865.4	6406.8	2950.4	6520.4	3037.8	6636.4	3127.6	6754.6	23
24	.4000	2866.7	6408.7	2951.8	6522.3	3039.3	6638.3	3129.1	6756.6	24
25	.4167	2868.1	6410.6	2953.3	6524.3	3040.8	6640.3	3130.7	6758.6	25
26	.4333	2869.5	6412.4	2954.7	6526.2	3042.2	6642.2	3132.2	6760.6	26
27	.4500	2870.9	6414.3	2956.2	6528.1	3043.7	6644.2	3133.7	6762.6	27
28	.4667	2872.3	6416.2	2957.6	6530.0	3045.2	6646.1	3135.2	6764.6	28
29	.4833	2873.7	6418.1	2959.0	6531.9	3046.7	6648.1	3136.7	6766.6	29
30	.5000	2875.1	6419.9	2960.4	6533.8	3048.1	6650.0	3138.3	6768.6	30
31	.5167	2876.5	6421.8	2961.9	6535.8	3049.6	6652.0	3139.8	6770.6	31
32	.5333	2877.9	6423.7	2963.3	6537.7	3051.1	6653.9	3141.3	6772.6	32
33	.5500	2879.4	6425.6	2964.8	6539.6	3052.6	6655.9	3142.9	6774.6	33
34	.5667	2880.8	6427.5	2966.2	6541.5	3054.1	6657.8	3144.4	6776.6	34
35	.5833	2882.2	6429.4	2967.7	6543.4	3055.6	6659.8	3145.9	6778.6	35
36	.6000	2883.6	6431.2	2969.1	6545.3	3057.0	6661.7	3147.4	6780.6	36
37	.6167	2885.0	6433.1	2970.6	6547.3	3058.5	6663.7	3149.0	6782.6	37
38	.6333	2886.4	6435.0	2972.0	6549.2	3060.0	6665.7	3150.5	6784.6	38
39	.6500	2887.8	6436.9	2973.5	6551.1	3061.5	6667.7	3152.0	6786.6	39
40	.6667	2889.2	6438.8	2974.9	6553.0	3063.0	6669.6	3153.5	6788.6	40
41	.6833	2890.6	6440.7	2976.4	6555.0	3064.5	6671.6	3155.1	6790.6	41
42	.7000	2892.0	6442.5	2977.8	6556.9	3066.0	6673.5	3156.6	6792.6	42
43	.7167	2893.4	6444.4	2979.3	6558.8	3067.5	6675.5	3158.2	6794.6	43
44	.7333	2894.8	6446.3	2980.7	6560.7	3068.9	6677.4	3159.7	6796.6	44
45	.7500	2896.3	6448.2	2982.2	6562.7	3070.4	6679.4	3161.2	6798.6	45
46	.7667	2897.7	6450.1	2983.6	6564.6	3071.9	6681.4	3162.7	6800.6	46
47	.7833	2899.1	6452.0	2985.1	6566.5	3073.4	6683.4	3164.3	6802.6	47
48	.8000	2900.5	6453.9	2986.5	6568.4	3074.9	6685.3	3165.8	6804.6	48
49	.8167	2901.9	6455.8	2988.0	6570.4	3076.4	6687.3	3167.4	6806.6	49
50	.8333	2903.3	6457.6	2989.4	6572.3	3077.9	6689.2	3168.9	6808.6	50
51	.8500	2904.7	6459.5	2990.9	6574.3	3079.4	6691.2	3170.5	6810.6	51
52	.8667	2906.1	6461.4	2992.3	6576.2	3080.9	6693.2	3172.0	6812.6	52
53	.8833	2907.6	6463.3	2993.8	6578.1	3082.4	6695.2	3173.6	6814.7	53
54	.9000	2909.0	6465.2	2995.2	6580.0	3083.9	6697.1	3175.1	6816.7	54
55	.9167	2910.4	6467.1	2996.7	6582.0	3085.4	6699.1	3176.6	6818.7	55
56	.9333	2911.8	6469.0	2998.1	6583.9	3086.9	6701.1	3178.1	6820.7	56
57	.9500	2913.3	6470.9	2999.6	6585.8	3088.4	6703.2	3179.7	6822.7	57
58	.9667	2914.7	6472.8	3001.1	6587.7	3089.9	6705.2	3181.2	6824.7	58
59	.9833	2916.1	6474.7	3002.6	6589.7	3091.4	6707.1	3182.8	6826.8	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	100° Ext.	100° Tan.	Minutes
0	.0000	3184.3	6828.8	0
1	.0167	3185.9	6830.8	1
2	.0333	3187.4	6832.8	2
3	.0500	3189.0	6834.8	3
4	.0667	3190.5	6836.8	4
5	.0833	3192.1	6838.9	5
6	.1000	3193.6	6840.9	6
7	.1167	3195.2	6842.9	7
8	.1333	3196.7	6844.9	8
9	.1500	3198.3	6847.0	9
10	.1667	3199.8	6849.0	10
11	.1833	3201.4	6851.0	11
12	.2000	3202.9	6853.0	12
13	.2167	3204.5	6855.1	13
14	.2333	3206.0	6857.1	14
15	.2500	3207.6	6859.1	15
16	.2667	3209.1	6861.1	16
17	.2833	3210.7	6863.2	17
18	.3000	3212.2	6865.2	18
19	.3167	3213.8	6867.2	19
20	.3333	3215.4	6869.2	20
21	.3500	3217.0	6871.3	21
22	.3667	3218.5	6873.3	22
23	.3833	3220.1	6875.4	23
24	.4000	3221.6	6877.4	24
25	.4167	3223.2	6879.4	25
26	.4333	3224.7	6881.4	26
27	.4500	3226.3	6883.5	27
28	.4667	3227.9	6885.5	28
29	.4833	3229.5	6887.6	29
30	.5000	3231.0	6889.6	30
31	.5167	3232.6	6891.7	31
32	.5333	3234.1	6893.7	32
33	.5500	3235.7	6895.7	33
34	.5667	3237.3	6897.8	34
35	.5833	3238.9	6899.8	35
36	.6000	3240.4	6901.8	36
37	.6167	3242.0	6903.9	37
38	.6333	3243.5	6905.9	38
39	.6500	3245.1	6908.0	39
40	.6667	3246.7	6910.0	40
41	.6833	3248.3	6912.1	41
42	.7000	3249.8	6914.1	42
43	.7167	3251.4	6916.2	43
44	.7333	3253.0	6918.2	44
45	.7500	3254.6	6920.3	45
46	.7667	3256.2	6922.3	46
47	.7833	3257.8	6924.4	47
48	.8000	3259.3	6926.4	48
49	.8167	3260.9	6928.5	49
50	.8333	3262.5	6930.5	50
51	.8500	3264.1	6932.6	51
52	.8667	3265.7	6934.6	52
53	.8833	3267.3	6936.7	53
54	.9000	3268.8	6938.7	54
55	.9167	3270.4	6940.8	55
56	.9333	3272.0	6942.8	56
57	.9500	3273.6	6944.9	57
58	.9667	3275.2	6946.9	58
59	.9833	3276.8	6949.0	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves
Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	101° Ext.	101° Tan.	102° Ext.	102° Tan.	103° Ext.	103° Tan.	104° Ext.	104° Tan.	105° Ext.	105° Tan.	Minutes
0	3278.3	6951.0	3375.1	7076.0	3474.6	7203.6	3577.1	7334.1	3682.6	7467.5	0
10	3294.3	6971.7	3391.5	7097.1	3491.5	7225.1	3594.4	7356.1	3700.4	7490.0	10
20	3310.3	6992.4	3407.9	7118.2	3508.4	7246.8	3611.9	7378.2	3718.4	7512.6	20
30	3326.4	7013.2	3424.5	7139.4	3525.5	7268.5	3629.4	7400.4	3736.5	7535.3	30
40	3342.5	7034.0	3441.1	7160.7	3542.6	7290.3	3647.1	7422.7	3754.6	7558.1	40
50	3358.8	7055.0	3457.8	7182.1	3559.8	7312.1	3664.8	7445.0	3772.9	7581.0	50
60	3375.1	7076.0	3474.6	7203.6	3577.1	7334.1	3682.6	7467.5	3791.2	7604.0	60

Minutes	106° Ext.	106° Tan.	107° Ext.	107° Tan.	108° Ext.	108° Tan.	109° Ext.	109° Tan.	110° Ext.	110° Tan.	Minutes
0	3791.2	7604.0	3903.1	7743.7	4018.5	7886.7	4137.4	8033.2	4260.0	8183.3	0
10	3809.6	7627.0	3922.1	7767.3	4038.0	7910.8	4157.5	8057.9	4280.8	8208.7	10
20	3828.1	7650.2	3941.2	7791.0	4057.7	7935.1	4177.8	8082.8	4301.7	8234.2	20
30	3846.7	7673.4	3960.4	7814.7	4077.5	7959.5	4198.2	8107.8	4322.7	8259.8	30
40	3865.4	7696.7	3979.6	7838.6	4097.3	7983.9	4218.7	8132.8	4343.8	8285.5	40
50	3884.2	7720.1	3999.0	7862.6	4117.3	8008.5	4239.3	8158.0	4365.1	8311.3	50
60	3903.1	7743.7	4018.5	7886.7	4137.4	8033.2	4260.0	8183.3	4386.4	8337.2	60

Minutes	111° Ext.	111° Tan.	112° Ext.	112° Tan.	113° Ext.	113° Tan.	114° Ext.	114° Tan.	115° Ext.	115° Tan.	Minutes
0	4386.4	8337.2	4516.9	8495.1	4651.6	8657.1	4790.7	8823.4	4934.4	8994.3	0
10	4407.9	8363.2	4539.1	8521.8	4674.5	8684.5	4814.4	8851.6	4958.9	9023.2	10
20	4429.5	8389.4	4561.3	8548.6	4697.5	8712.0	4838.1	8879.9	4983.4	9052.3	20
30	4451.2	8415.6	4583.7	8575.6	4720.6	8739.7	4862.0	8908.3	5008.1	9081.5	30
40	4473.0	8442.0	4606.2	8602.6	4743.9	8767.5	4885.0	8936.8	5032.9	9110.8	40
50	4494.9	8468.5	4628.9	8629.8	4767.2	8795.4	4910.2	8965.5	5057.9	9140.3	50
60	4516.9	8495.1	4651.6	8657.1	4790.7	8823.4	4934.4	8994.3	5083.0	9169.9	60

Minutes	116° Ext.	116° Tan.	117° Ext.	117° Tan.	118° Ext.	118° Tan.	119° Ext.	119° Tan.	120° Ext.	120° Tan.	Minutes
0	5083.0	9169.9	5236.6	9350.5	5395.4	9536.3	5559.7	9727.6	5730.0	9,924.6	0
10	5108.2	9199.7	5262.6	9381.1	5422.4	9567.8	5587.7	9760.0	5758.9	9,958.1	10
20	5133.6	9229.6	5288.9	9411.9	5449.5	9599.5	5615.8	9792.6	5788.0	9,990.6	20
30	5159.1	9259.6	5315.3	9442.8	5476.8	9631.3	5644.1	9825.4	5817.3	10,025.6	30
40	5184.8	9289.8	5341.8	9473.8	5504.3	9663.2	5672.6	9858.3	5846.8	10,059.7	40
50	5210.6	9320.1	5368.5	9505.0	5532.0	9695.3	5701.2	9891.4	5876.4	10,093.7	50
60	5236.6	9350.5	5395.4	9536.3	5559.7	9727.6	5730.0	9924.6	5906.1	10,127.7	60

$$L = 100 \times \frac{\triangle}{D} = \frac{\text{central angle}}{\text{Degree of curvature}} \times 100.$$

For the convenience of the field engineer column 1, Table 30, gives the central angle ($\triangle$) in degrees and minutes (as read by the transit); column 2 gives the same angle expressed in degrees and decimals for figuring curve lengths.

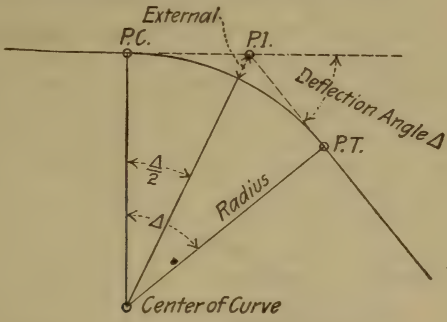


FIG. 52

Tangent length and externals.

Sketch No. 52 shows a general curve problem. The deflection angle between the tangents at the point of intersection (P.I.) = the central angle of the curve that will fit these tangents; it is referred to as $\triangle$.

The tangent distances equal the distance from the *P. C.* (beginning of curve) to the *P. I.* or *P. I.* to *P. T.* (end of curve) and is expressed by the formula

$$\text{T} = \text{Radius} \times \text{tangent of } \frac{\triangle}{2} \qquad (4)$$

Therefore, for a given central angle $\triangle$, the tangent length is directly proportional to the radius. If the tangent lengths of a 1° curve for different $\triangle$'s are tabulated, the tangent length for any desired degree of curve equals tangent length for 1° curve for the specified $\triangle$ divided by the degree of the desired curve expressed in degrees and decimals of a degree.

Expressed as a formula this reads:

$$\text{Tangent for desired curve} = \frac{\text{Tangent } 1° \text{ curve for specified } \triangle}{D} \qquad (5)$$

and reversing the formula we can determine the desired degree of curve for a specified tangent length by the formula

$$D = \frac{\text{Tangent } 1° \text{ curve for specified } \triangle}{\text{Specified tangent length desired.}} \qquad (6)$$

The external is the distance from the *P. I.* to the curve arc on the line between the *P. I.* and the center of the curve. It is determined by the formula:

$$\text{Ext} = \frac{\text{Radius}}{\text{Cosine } \frac{\triangle}{2}} - \text{Radius} = \text{Radius}\left(\frac{1}{\text{Cosine } \frac{\triangle}{2}} - 1\right) \qquad (7)$$

and is directly

proportional to the radius in the same manner as the tangent length; therefore, the external of any desired curve for a specified $\triangle$ equals the external of a 1° curve for that $\triangle$ divided by the degree of curvature.

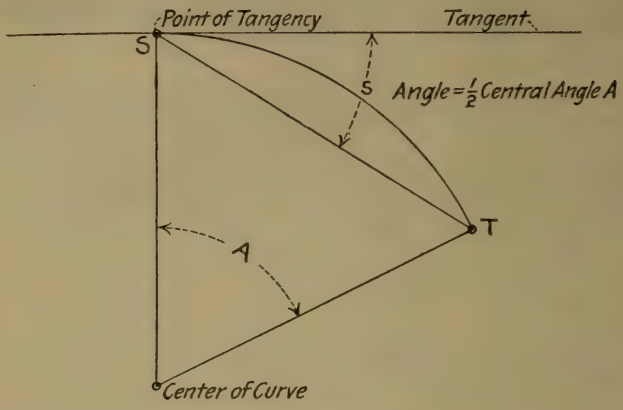


FIG. 53

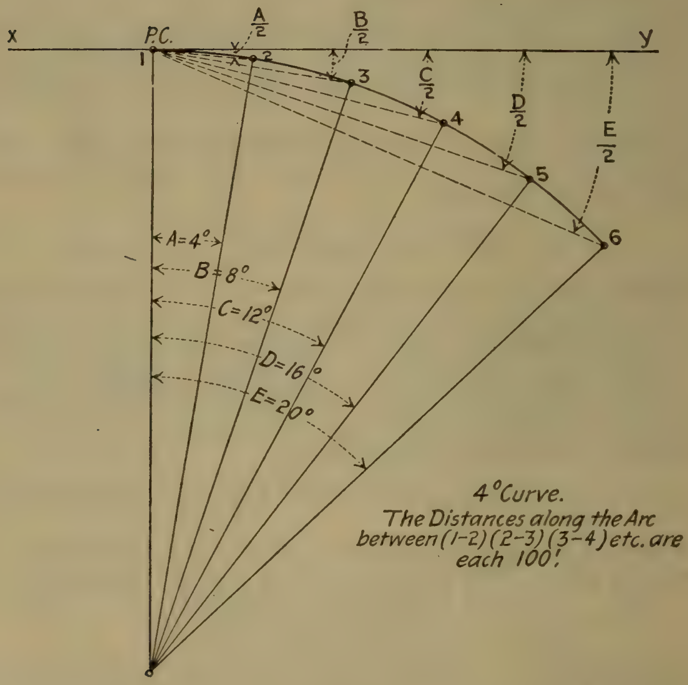


FIG. 54

Expressed as a formula this reads:

$$\text{External for desired curve} = \frac{\text{Ext. 1° curve for specified } \triangle}{D} \quad (8)$$

and reversing, as for tangents, the desired degree of curvature is obtained that gives a specified external distance, by the formula,

$$D = \frac{\text{Ext. } 1^\circ \text{ curve for specified } \Delta}{\text{Specified Ext. distance desired.}} \qquad (9)$$

Methods of running curves. Curves are run in the field by tangent offsets, middle ordinates or deflection angles. Deflection angles is the simplest method and is almost universally used. It is based on the principle that the angle S between the tangent and arc chord, one end of which is at the point of tangency, is equal to $\frac{1}{2}$ the central angle subtended by that chord. Suppose the angle A is 4° and the arc length ST = 100 feet. This curve would then be a 4° curve. From the previous definitions locate the point T (Fig. 53) by turning the deflection angle S = 2° from the tangent and measuring 100 feet of arc in such a position that the end of the arc would be on the line of the chord ST. It is impossible to conveniently measure the arc distance and for all practical purposes a chord length of 100′ will answer for a 4° curve (see discussion, page 173).

Suppose we wish to locate the points 2, 3, 4, 5, and 6 on the 4° curve from point 1 or the $P. C.$ of a curve (Fig. 54).

Set the transit at the $P. C.$; if we turn a deflection $\frac{A}{2}$ = 2° from the tangent xy the line of sight will pass through the point 2; if we turn $\frac{B}{2}$ = 4° the line of sight will pass through point 3; 6°, point 4, etc.; it only remains to measure to these points to locate them definitely. This can be done in two ways, by measuring the distances 1–2, 1–3, 1–4, 1–5, etc., or by measuring 1–2, 2–3, 3–4, 4–5, etc.

In the first case the difference between the length of arc and the chord length becomes so great that, unless a correction is made, the points are not exactly located; that is, the length of arc between points 1, 2, 3, 4, 5, 6, = 500′ while the chord length 1–6 = 497.5′; also, it takes longer to measure the distances 1–2, 1–3, 1–4, 1–5, 1–6, etc., than it would 1–2, 2–3, 3–4, 4–5, etc.

In the second method we can use chords of 100′ from 1–2, 2–3, etc., with no appreciable error, as the distance measured by chords 1, 2, 3, 4, 5, 6, = 499.94′.

Therefore, the method usually adopted is to turn the deflection angle $\frac{A}{2}$ and measure the chord 1–2, which locates the point 2; then turn the deflection angle $\frac{B}{2}$ and measure the chord distance 2–3, locating point 3, etc.

The fact has been mentioned that the use of the chord distance as equal to the arc introduces an error but that this error is of no importance for a 4° curve: As the degree of curvature increases, the difference between an arc length of 100′ and the chord length becomes greater, and it is necessary to determine the limit of curvature that will allow the use of 100′ chords in locating curve

points. On page 145 the statement is made that center line chaining should be correct to within 0.1′ per 100′ of length, which allows a difference in arc and chord of 0.1′ This occurs when the degree of curvature reaches 9° per 100′. The difference can then be reduced by the simple expedient of using 50′ chords, which reduces the error for this degree of curvature from 0.10′ per 100′ of length using 100′ chords to 0.02′ using 50′ chords; 50′ chords can be used up to 18° curves and beyond that point 25′ chords.

It is better not to use the full limit of allowable error, and a good working rule is 100′ chords up to 8° curves, 50′ chords up to 16° curves, 25′ chords to 32° and beyond that 10′ chords.

For any given curve the deflection angle and central angle are directly proportional to the length of the arc, and if the deflection angle for 100′ arc of 10° curve equals 5° the deflection angle for one foot of arc of 10° curve equals $\frac{5°}{100} = \frac{300'}{100} =$ 3 minutes.

An example of a typical simple curve problem can now be given:

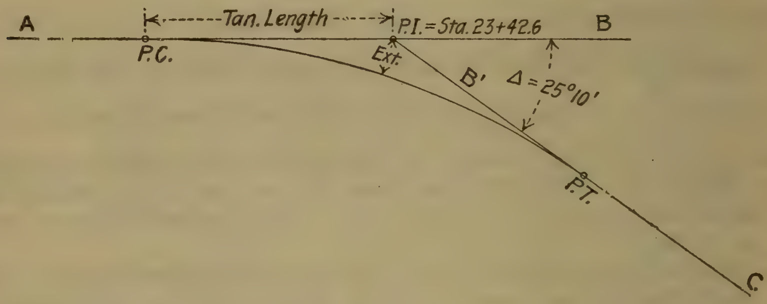


FIG. 55

To determine the degree of curvature desired from a fixed external distance

At station 23 + 42.6 we have a deflection angle of 25° 10′ between tangents *AB* and *B′C*; suppose upon examining the ground it is decided that to fit the old roadbed and give good alignment the curve should be located somewhere between 13.5′ and 14.5′ to the right of the transit point at station 23 + 42.6. Proceed as follows: from table 30 pick out the external for a 1° curve for Δ = 25° 10′, this equals 141.0′.

The problem is to determine the degree of curvature that will give an external of between 13.3′ and 14.5′. Use formula (9).

$$D = \frac{\text{Ext. } 1° \text{ curve for } 25° \ 10'}{13.5'} = \frac{141.0'}{13.5'}, = 10.44° \text{ curve.}$$

$$D = \frac{\text{Ext. } 1° \text{ curve for } 25° \ 10'}{14.5'} = \frac{141.0'}{14.5} = 9.72° \text{ curve.}$$

To fit the conditions some curve must be selected between a

10.44° and a 9.72°. A 10° curve would be naturally selected as being the simplest to figure.

To determine the required degree of curvature for a fixed tangent length

Take the same problem as above except there must be a tangent length of between 127′ and 129′. Use formula (6).

$$D = \frac{\text{Tangent } 1° \text{ curve for } 25° \ 10'}{127'} = \frac{1279.1'}{127'} = 10.07° \text{ curve.}$$

$$D = \frac{\text{Tangent } 1° \text{ curve for } 25° \ 10}{129'} = \frac{1279.1'}{129'} = 9.91° \text{ curve.}$$

Table No. 30 gives tangent for 25° 10′ = 1279.1′.

These limiting values would result in the selection of a 10° curve. The degree of the desired curve is usually selected in one of these two ways; ordinarily it is determined by the external distance.

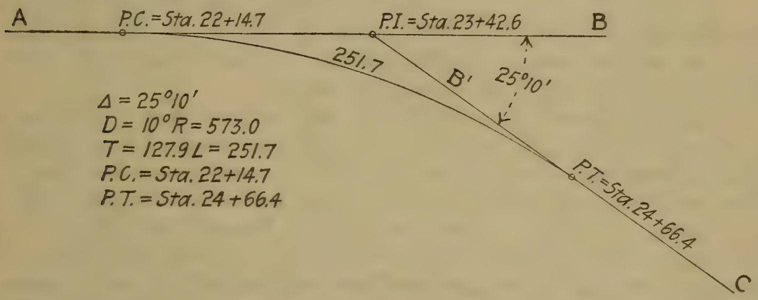


FIG. 56

Simple Curve Problem. Case 1.

To compute the notes for a 10° curve for a deflection angle of 25° 10′ between tangents at station 23 + 42.6.

Central angle = 25° 10′.

Table No. 30 gives the tangent 1° curve for 25° 10′ = 1279.1.

$$\text{Tangent } 10° \text{ curve} = \frac{1279.1}{10} = 127.91$$

The station of the *P.C.* then equals station 23 + 42.6 *P.I.* minus 127.9′ = station 22 + 14.7.

$$\text{The length of curve} = \frac{\Delta}{D} = \frac{25.16667°}{10°} \times 100' = 251.7 \text{ feet.}$$

The station of the *P.T.* (Tangent point, or end of the curve) as measured around the arc is then station (22 + 14.7 *P.C.*) + 251.7′ = station 24 + 66.4.

The rule for running curves requires the use of 50′ chords for a 10° curve. We must, therefore, figure the deflections for the even stations and the 50′ stations as follows:

Station 22 + 50, 23 + 00, 23 + 50, 24 + 00, 24 + 50, and to check the curve station 24 + 66.4.

For a 10° curve, Table No. 29.

The deflection for 100′ of arc = 5°
" " " 50′ " " = 2° 30′
" " " 1′ " " = 0° 03′

The distance from the *P.C.* station 22 + 14.7 to station 22 + 50 is 35.3′; the deflection per foot = 0° 03′, for 35.3′ = 35.3 × 0° 03′ = 105.9 minutes = 1° 46′.

The distance *P.C.* to station 23 + 00 equals 85.3′, or 50′ farther than for station 22 + 50; the deflection per 50′ of arc equals 2° 30′; therefore, the deflection for station 23 + 00 equals the deflections for station 22 + 50 (1° 46′) plus 2° 30′, the deflection for 50′ of arc or 4° 16′; in a like manner the deflection for station 23 + 50 is 6° 46′; for 24 + 00, 9° 16′; for 24 + 50, 11° 46′; the distance from station 24 + 50 to the *P.T.* station 24 + 66.4 is 16.4′; the deflection for 16.4′ equals 16.4 × 0° 03′ = 49.2′; the deflection for station 24 + 66.4 is, therefore, (11° 46′ + 49′) = 12° 35′; if the deflection notes have been properly figured this last deflection to the *P.T.* should always be ½ the central angle of the curve; in this case ½ of 25° 10′, which equals 12° 35′, checking the notes.

To run the curve. Set up the transit at the *P.I.*; sight along the tangent (*B.A.*), measure off the distance 127.9 (tangent length) along this line and set the *P. C.* exactly on the line. In a like manner set the *P.T.* on the forward tangent (*B′.C.*) 127.9′ from the *P.I.* Then set up the transit on the *P.C.* and with the vernier at 0° 00′ sight on the *P.I.*, using the lower plate motion. Loosen the upper motion and deflect 1° 46′; measure along this line 35.3′, which locates station 22 + 50 on the curve arc; then loosen the upper motion and set the vernier to read 4° 16′; measure 50′ from the just located station 22 + 50, so that the forward end of the tape is in line with the transit deflection of 4° 16′; this locates station 23 + 00 on the curve arc. In a like manner deflect 6° 46′ and measure forward 50′ from station 23 + 00 to station 23 + 50, etc., until the *P.T.* is reached. If the curve has been correctly run the last deflection of 12° 35′ will strike the previously located *P. T.* and the distance from station 24 + 50 to this *P.T.* will be 16.4′; if the distance checks within 0.2′ it is sufficiently close.

The above problem and method of laying out a curve is the simplest form encountered; in it we assume that the *P.I.*, *P.T.* and all intermediate points on the curve are visible from the *P.C.* and that the *P.I.* is accessible.

In nine cases out of ten this method is applicable to road curves, but where the *P.I.* occurs outside of the road fences it sometimes is located in a stream, pond, building, etc., and cannot be occupied. This is known as the problem of the inaccessible *P.I.* More often it is impossible to see the *P.T.*, or some intermediate point on the curve from the *P.C.*, which necessitates intermediate transit points on the curve. The problem of inaccessible *P.C.s* or *P.T.s* is so rare it will not be illustrated.

Problem of the Inaccessible P. I. Case 2.

The point H ($P.I.$) cannot be occupied. Locate any two convenient points, s and t on the tangents $A.B.$ and $B'.C.$ and measure the distance st equals, say, 110.5′.

Set the transit at s and measure the angle between the line $A.s.$ produced and st, say, 5° 10′; in a similar manner measure the angle at t between st produced and the forward tangent tC, say, 20° 00′. The total deflection then between the tangent AsB and $B'tC$ or the central angle of the curve to be run is the sum of these two deflections, angles (5° 10′) + (20° 00′) = 25° 10′.

Assuming a 10° curve is desired we must locate the $P.C.$ from the point s and the $P.T.$ from the point t.

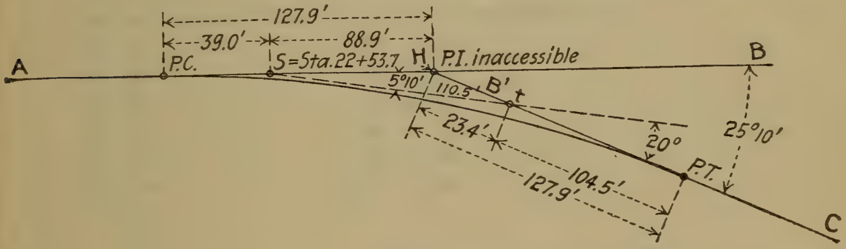


FIG. 57

In the preceding simple curve problem the tangent length of a 10° curve with a central angle of 25° 10′ was figured to be 127.9′; it, therefore, remains to compute the distance sH which subtracted from 127.9′ will give the distance from s along the tangent sA to the $P.C.$, of the curve. In a similar manner compute tH, which subtracted from 127.9′ gives the distance along the forward tangent tC to the $P.T.$ of the curve.

Knowing the station of the point s as measured along the tangent $A.B.$ the station of the $P.C.$ is determined; then figure the deflections in the usual manner and run the curve.

For the values given the computations are as follows:

To determine sH and Ht. Use the law of sines (see Trigonometric formulæ, page 477).

$sH : st : \sin 20°\ 00' : \sin 25°\ 10'$

$$sH = \frac{st \sin 20°\ 00'}{\sin 25°\ 10'} = \frac{110.5 \times 0.34202}{0.42525} = 88.87'$$

$$Ht = \frac{st \sin 5°\ 10'}{\sin 25°\ 10'} = \frac{110.5 \times 0.09005}{0.42525} = 23.4'$$

Therefore, the distance from s to the $P.C.$ is 127.9′ − 88.9′ = 39.0′.

The distance from t to the $P.T.$ is 127.9 − 23.4 = 104.5.

Having these distances the $P.C.$ and $P.T.$ are located. Assume that station of s was measured along the tangent AB and found to be station 22 + 53.7.

The station of the *P.C.* then equals 22 + 14.7
" " " " *P.I.* " " 23 + 42.6
" " " " *P.T.* " " 24 + 66.4, using the length of curve figured in *Case* 1.

The deflections are figured and the curve run as in Case 1, assuming that all the curve points are visible from the *P.C.*

Case 3. *Where the P.T. or intermediate points on the curve are not visible from the P.C.*

(*a*) *Where an intermediate set-up is required. Use the same curve as in Case* 1.

The deflections for the different curve points were figured as follows:

Deflections. Instrument at P.C., foresight on P.I.

P.C. Station	22 + 14.7	Deflection	0° 00′
	22 + 50	"	1° 46
	23 + 00	"	4° 16′
	23 + 50	"	6° 46′
	24 + 00	"	9° 16′
	24 + 50	"	11° 46′
	24 + 66.4	"	12° 35′

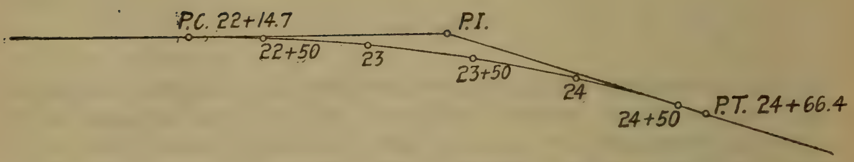


FIG. 58

Set up the instrument at the *P.C.* and locate the points 22 + 50, 23 + 00 and 23 + 50; suppose 24 + 00 is not visible, set up at station 23 + 50, set the vernier at 0° 00′ and back sight on the *P.C.*; transit the telescope and finish the curve, using the same deflections as figured for the instrument set up at the *P.C.*; that is, turn the deflection of 9° 16′ for station 24 + 00, 11° 46′ for 24 + 50, and 12° 35′ for the *P.T.* In general it can be said that whenever the *P.C.* is used as a back-sight from the intermediate set-up, set the vernier at 0° 00′ when sighting on the *P.C.*; transit the telescope and use original notes for the balance of the curve.

(*b*) *Where two or more intermediate set-ups are required.*

For the first set-up, say, at 23 + 50, proceed as above and set station 24 + 00; suppose 24 + 50 is not visible from station 23 + 50; set up at station 24 + 00 and with the vernier reading 6° 46′ back sight on station 23 + 50; transit the telescope, set the vernier to read 11° 46′ for station 24 + 50, and proceed, using the same deflections as originally figured. In general, where the *P.C.* is not visible from the intermediate set-up, set the

vernier to read the deflection figured for the point used as a backsight; transit the telescope and proceed with the curve, using the notes originally figured. That is, if the instrument is set up at station 24 + 00 and 22 + 50 used as a backsight, the vernier is set at 1° 46′, and using the lower motion the wire is set on station 22 + 50; then transiting the telescope the curve is run by setting the vernier at 11° 46′ for station 24 + 50, etc.

If station 23 + 00 is used as a backsight, set the vernier at 4° 16′ when sighting the machine; then transit and proceed as above.

These three cases cover any ordinary road curve problems.

CHAPTER IX

OFFICE PRACTICE

Under office practice we include

1. Mapping the preliminary survey.
2. Designing the improvement and estimating the quantities.
3. Producing a finished set of plans from which the road can be constructed.

1. Mapping the preliminary survey.

The mapping of the preliminary survey serves as a base from which the design of the new work, and the quantities necessary thereto, can be built up. It consists of three views of the road: the plan, showing the topographic features; the profile, showing the longitudinal differences of elevation, and the cross-sections, showing the constantly changing transverse shape.

The scales in general use are as follows:

Plan	Profile	Cross-sections
1″ = 100′	1″ = 100′ horizontal 1″ = 10′ vertical	1″ = 10′
1″ = 50′	1″ = 50′ horizontal 1″ = 10′ vertical	1″ = 5′ or 1″ = 4′
1″ = 20′	1″ = 20′ horizontal 1″ = 5′ vertical	1″ = 5′ or 1″ = 4′
1″ = 10′	1″ = 10′ horizontal 1″ = 10′ vertical	1″ = 2′

The 100′ scale is too small for convenience in design, and earthwork quantities figured from cross-sections plotted 1″ to 10′ are not reliable. For work on ordinary country roads, the 50′ scale is generally adopted, using cross-sections plotted 1″ to 5′ or 1″ to 4′; this scale is satisfactory for laying the grade line and computing the earthwork.

The larger scales of 1″ = 20′ or 1″ = 10′ are useful in village work where a large amount of detail must be shown.

Plotting the center line.

The survey center line can be plotted by deflection angles at the transit points, using a table of natural tangents, a vernier

protractor or an ordinary paper protractor graduated to 15 minutes.

Where the center line has been well located in the field and there seems to be no necessity for a paper re-location, no great care need be taken in plotting the deflection angles, as in such a case the map serves more as a picture of the topographic features than as a basis for alignment.

Where a random line has been run in the field and some shifting of the center line is necessary, both angles and distances must be accurately plotted. If any extensive change of alignment is made, the new deflections and distances should be checked by figuring the difference of latitude and longitude for both the survey line and the office line between the points of equality.

Where the consideration of sight distance (see page 17) governs, Table No. 31 will be of service.

For convenience in plotting the topography, the 100′ survey stations are plainly marked.

The most common mistakes in plotting the map are made by reversing the deflection, as right instead of left and *vice versa*, or in adding or omitting 100′ in scaling long-tangent distances.

The work should be checked for mistakes of this nature.

All curve data is marked plainly on the map near the *P.I.* and shows

The deflection angle $\triangle$
The degree of curve D
The radius of curve R
The tangent length T
The length of curve L
The station of the *P.I.*
The station of the *P.C.*
The station of the *P.T.*

If the curves have been figured in the office and have not been run in the field it is good practice to scale the offsets from the tangent to the curve and mark them on the map.

These offsets from the center line as run are then transferred to the cross-sections and the profile plotted from center line elevations on the cross-sections.

Table No. 31 gives the approximate distance that an automobile driver can see an approaching car, assuming that he is driving in the center of the macadam and that the approaching car is also in the center. Two distances are given for each curve, the first assuming that the line of sight is six feet from the ground, which is about right if the curve is on a straight grade, and makes the line of sight tangent to the cut slope of 1 on $1\frac{1}{2}$ 19 feet off center for the narrow section shown in Fig. No. 7, page 30, and, second, assuming that the line of sight is close to the ground, as occurs on rounding the top of a hill, in which case the line of sight will be tangent to the side slope at, approximately, 11′ off center.

TABLE 31

Degree of Curvature	Radius of Curve Feet	Sight Distance Case One. Feet	Sight Distance Case Two. Feet
5	1146.0	400	310
6	955.0	375	290
7	818.6	350	270
8	716.3	330	250
9	636.6	310	235
10	573.0	295	220
12	477.5	270	200
14	409.3	245	185
16	358.1	230	175
18	318.3	220	165
20	286.5	210	160
30	191.0	170	130
40	143.2	145	110
50	114.6	130	100

Plotting the topography.

If the topography has been recorded on a system of right-angle offsets, as suggested and illustrated on page 123, it can be easily and quickly plotted by using the transparent scale shown here.

This scale gives the plus distance along the survey base line, or center line, and the offset distance from the line in one operation.

As a general rule the plotting of the topography need not be checked.

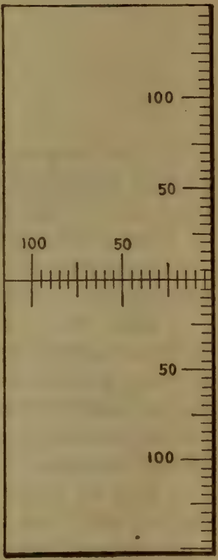


FIG. 59.—Convenient Transparent Scale for Plotting Topography

Level Computations.

The survey computations of the Bench Levels are checked and a list of bench elevations prepared; these elevations are used in cross-section level notes and from them the notes are computed between benches. As each bench is reached these notes are corrected to agree with the elevation adopted for that bench and then carried forward on the corrected basis. The allowable error for cross-section levels, as mentioned in the chapter on surveys, is less than 0.1 feet. The correction of the levels at each bench prevents any cumulative error and makes the elevations of the cross-section shots agree with the adopted bench elevations with an error of less than 0.1′. This is as close as the

readings can be plotted and as close as they can be read in the field.

The computation of the bench levels and the adjustment of the cross-section notes should be checked by a competent man. The most common mistake in figuring the cross-section readings is to use the wrong height of instrument for a section. Such a mistake cannot be detected in plotting the sections, but is generally discovered when the profile is plotted.

In checking the notes particular care should be taken on this one point.

Plotting the cross-sections.

The cross-sections must be *very carefully* plotted, as the reliability of the earthwork computation depends largely on their accuracy.

The cross-section paper used should be exact in the divisions and should be printed or engraved from plates.

Ruled paper is inaccurate.

The plotting is checked by reliable men. Reading the shots back from the plotted cross-section is preferable to reading them from the book. The elevations of the center line and of the ditch line are written over the section. The station number or plus of each section is written on the right margin. The fact that the section has been graveled within the traveled way, that stone has been spread to a certain thickness, or any other fact that would influence the designer when laying a grade line, is noted on the section. See Fig. 60.

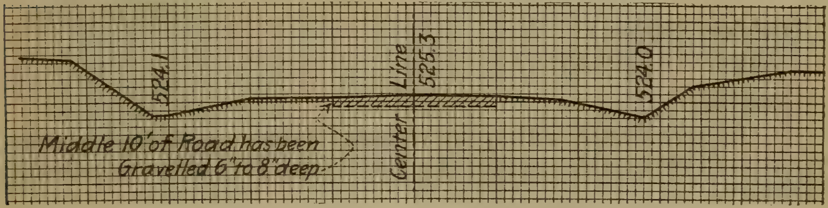


FIG. 60

It is common practice to allow the inexperienced men to plot and check the cross-sections. We believe this is a mistake. This part of mapping is the most important of the preliminary plans; and the work should be plotted and checked so that the points are correct to the nearest 0.1 feet in elevation.

These points are then connected with a fine ink line.

Plotting the profile.

The profile is plotted from the center-line elevations given in the cross-section notes unless the proposed center line does not coincide with the survey center line, in which case the elevations

of the proposed line are projected from the previously plotted cros-s sections.

It is not necessary to spend so much time for accuracy in plotting as on the sections, as the profile only serves as a guide in laying the grade line and no quantities depend upon its correctness. An error of 0.2 feet is allowable.

The elevation of each plotted center-line point is recorded with its stationing.

See Fig. 63.

The Design.

The completion of the profile finishes the preliminary mapping. The first operations of the office design are as follows:

A. The selection of section.

B. The depth of metalling.

C. The laying of the grade line.

These three points are so dependent on each other that they cannot be separated.

The most experienced man available should do this part of the work. He should be thoroughly familiar with the road from field inspection, and in designing he follows the general principles discussed in the chapters on Grades, Sections, and Foundations. His selection depends on a report of this character.

PRELIMINARY DESIGN REPORT, NEW CONSTRUCTION

Dec. 10, 1914.

Division Engineer
Dept. of Highways

Dear Sir:

In accordance with your request of Nov. 25th find enclosed report on a reasonable cost for the Town Line-Manitou State-County Highway.

General Report and Estimate, Town Line—Manitou State-County Highway

With a proper use of local materials a satisfactory road can be built at a cost of $94,000 or approx. $11,000 per mile including Engineering and Contingencies. An expenditure of $12,000 per mile would not however be excessive.

The Braddocks Bay crossing is the expensive feature of this road; it raises the cost of the entire road about $1,000 per mile.

Design No. 1 is recommended (see page 217).

A detail report follows.

Signed

Designing Engineer.

Detail Report and Estimate, Town Line — Manitou State-County Highway

Length. 8.51 miles from the Ridge Road to Manitou Beach.

Foundation Soil. Heavy soil not particularly good foundation Sta. 0 to 133; sandy soil balance of distance except across Braddocks Bay. A 9″ thickness of some form of macadam is advisable Sta. 0 to 133; 7″ or 8″ the balance of the distance should be satisfactory except across Braddocks Bay where it is safe to figure on 12″ to 15″ of Stone.

Grade. The present surface can be followed closely. The excavation should not exceed 2800 cu. yds. per mile except across Braddocks Bay; a rough estimate of borrow excavation for this fill is 15,000 cu. yds.

Alignment. Good; no right of way required except possibly at Sta. 350 near the schoolhouse at the turn to Manitou.

Traffic and Section. There is a heavy volume of automobile pleasure traffic and a light volume of heavy hauling traffic on this road.

The large amount of pleasure travel requires from 16′ to 18′ of stone surface; the heavy hauling does not require over 12′ to 14′ full depth metaling. We recommend a graded section 26′ to 28′ wide between ditches in cut with a 12′ width of full depth metal with 6′ of extra width of local crusher run on the shoulders Sta. 0 to 133; a 14′ width with 4′ of stone on shoulders Sta. 133 to 260; a width of 12′ of full depth metal with 6′ of stone on shoulders the balance of the distance except across Braddocks Bay where the entire width of metaling 16′ should have the full depth.

This road carries so much high speed traffic that it requires some form of bituminous macadam or if Waterbound is selected, it should be treated with calcium chloride immediately and have a surface coat of bitumen applied within three months.

Railroad Crossings. Sta. 223 R. W. & O. Ry. crossing; no gates or flagman. In the summer time the crossing should have a flagman as the orchards cut off the view. The crossing is not particularly dangerous, but during this season of the year the traffic on this road is entitled to better protection at this point.

The approach grade from the south should be made easier.

Drainage. No special features; approx. cost $3,500 exclusive of bridges above 5′ span to be built by the towns.

Dangerous Places. The Braddock Bay crossing is a dangerous one as the fill is high and the swamp is full of semi-fluid muck from 6′ to 12′ deep; a first-class concrete guard rail protection should be provided.

MATERIALS

Filler Sand. In abundance along road and from roadbed excavation.

Gravel. The only good gravel is Lake Gravel; this can be obtained up to approx. 6000 cu. yds. 1½ miles north of Sta. 350 and 3000

yds. ½ mile west of Sta. 450. Probably this gravel can be used to advantage (screened or selected beach run) as bottom course Sta. 350 to 450 or as filler for sub-base bottom and on the shoulders.

Stone. 15,000 cu. yds. of fence stone are available within a mile and a half of the road Sta. 0 to 133.

There is practically no local stone Sta. 133 to 350.

4,000 cu. yds. of fence stone are available within 1½ miles of Sta. 350.

This material runs about 20% granite fit for top and the balance soft sandstone fit for bottom either as a sub-base bottom or crushed stone bottom.

There is sufficient stone at the south end of the road to build a sub-base bottom with crushed stone filler; a local granite top with crushed stone on the shoulders from Sta. 0 to 133 and a local crushed stone bottom 5″ thick Sta. 133 to about Sta. 200.

There is sufficient stone at the north end to build about 1¾ miles of crushed stone bottom with stone on shoulders or 1½ miles of sub-base bottom with crushed stone filler and crushed stone on shoulders. I do not think there is enough granite to make it worth while to try and use a local top on any part of the north end.

It is probably better to use an imported top from Sta. 133 to 450 and imported bottom Sta. 200 to 280.

(See detail Stone Statement and Computations.)

Crusher set up at Sta. 100. 15,000 cu. yds. field stone available within 3 miles maximum haul. Average haul 1¼ miles.

Assume for safety that only 11,000 cu. yds. are available with an average haul to crusher of 1 mile.

Of this 11,000 cu. yds. field stone:

3,000 c. y.	used for sub-base bottom average haul ¼ mile	
1,000 c. y.	" " crushed stone filler	haul to crusher ½ mile " from " ¾ "
700 c. y.	" " " " shoulders	haul to crusher ½ mile " from " ¾ "
2,500 c. y.	" " Top course	haul to crusher 1 mile " from " ¾ "

7,200 c. y. field stone used for local macadam, from Sta. 0. to 133, leaving 3,800 c. y. available for crushed bottom and shoulder stone for road north of Sta. 133.

3,800 cu. yds. will produce approx. 3,000 cu. yds. of crushed bottom loose measure or about 2,300 cu. yds. of rolled measure. This will build 10,600 lin. ft. of 5″ bottom 14′ wide. We can therefore safely specify local bottom to Sta. 200 which will leave enough shoulder stone to use as far north as Sta. 300 if necessary.

Crusher set up at Sta. 350. 4,000 cu. yds. available within 1½ miles, say average haul 1 mile.

Assume for safety that 3,000 cu. yds. only are available average haul 1 mile. This will produce about 2400 cu. yds. crushed bottom stone loose measure or approx. 1,800 cu. yds. rolled measure. 1800 cu. yds. will build approx. 90 sta. of 12′ bottom 5″ deep which makes it safe to specify a local bottom using crushed stone and lake gravel

as far south as Sta. 280 with either gravel or crusher run the entire length of road on the shoulders.

Imported bottom should be used Sta. 200 to 280.

Imported Stone. \$1.25 per ton f. o. b. switch. Switch can be built at Sta. 233 for \$300 to \$400.

Water. Can be obtained at all seasons at intervals from 1 mile to $1\frac{1}{2}$ miles all along the road.

Cost of Different Types

Grubbing and clearing	\$ 300.00
23,000 cu. yds. Roadbed excavation @ \$.50	11,500.00
15,000 " " Brow Exc. across Braddock Bay @ \$.45	6,750.00
800 " " Sub.-base @ \$1.25	1,000.00
4,000 lin. ft. Concrete G. R. across Braddock's Bay @ \$1.00	4,000.00
Drainage of system	3,500.00
Minor points @ 400 per mile	3,400.00
Engineering and Contingencies	8,000.00
Total cost of items other than metalling	\$38,450.00

Schedule of Unit Prices

Imported Waterbound Top Sta. 133 to 450	\$5.00 per cu. yd. rolled
" Bit. Mac. " " " " "	7.30 " " " "
*Local Granite Bit. Mac. Top Sta. 0 to 133	6.00 " " " "
*Imported Limestone Water Mac. Sta. 0 to 133	5.50 " " " "
Sub-base Bottom Crushed stone filler 0 to 133	1.50 " " " "
Local crushed Bottom Sta. 133 to 200	2.50 " " " "
Imported Mac. Bottom Sta. 200 to 280	3.20 " " " "
Local Crushed Bottom Sta. 280 to 350	2.30 " " " "
Lake Gravel Bottom Sta. 350 to 450	1.90 " " " "
Crushed stone or gravel on shoulders	1.50 " " " loose
Tarvia B	0.08 per gal. in place

Table of Comparative Cost

Type	Approx. Cost including Eng. and Contingencies	
	Cost per mile	Total Cost
Design No. 1 (For details see Cost. Est. Sheet)	\$11,000	\$ 93,500
Design No. 2 (" " " " " ")	11,300	96,200
Design No. 3 (" " " " " ")	12,000	102,200
Design No. 4 (" " " " " ")	12,500	106,000

Computation of Unit Prices

Overhead approx. 30¢ per cu. yd. of Bottom and Top Stone. No overhead estimated on other items.

* *Note.* — There is no difference in cost Sta. 0–133 between a local granite Bit. Mac. Top and an imported limestone Waterbound Top when treated with Tarvia B.

Sub-base Bottom Course Crushed Stone Filler Sta. 0–133

Cost of Stone in fences	$0.10
Loading	0.15
Hauling $\frac{1}{4}$ mile	0.12
Placing and Sledging	0.20
Rolling	0.05
Crushed Stone Filler (See Filler) 0.35 cu. yd.	0.40
	$1.02
20% profit	.20
Overhead	0.30
Estimate	$1.52
Say $1.50	

Crushed Stone Filler (Crusher Run)

	per cu. yd.
Cost of stone in fences	$0.10
Loading	0.15
Haul to crusher 1 mile	0.35
Crushing	0.10
Cost in bins	$0.70
Loading to wagons	0.01
Haul to road $\frac{3}{4}$ mile	0.22
Spreading and brooming	0.20
	$1.13
0.35 cu. yd. per yd. of Sub-base =	$0.40

Local Crushed Stone Bottom Sta. 133 to 200

Cost in bins	$0.70
Loading to wagons	0.01
Hauling to road $1\frac{1}{4}$ miles	0.40
Spreading	0.06
Rolling	0.05
	$1.22
Consolidation 0.3	0.37
	$1.59
Filler	0.20
	$1.79
20% profit	0.36
Overhead	0.30
Say $2.50	$2.45

Stone on shoulders $1.50 per cu. yd. loose.

Local Granite Bit. Mac. Top Sta. 0 to 133

Stone in fences	$0.10
Loading	0.15
Blasting and sledging	0.15
Hauling to crusher	0.35
Crushing	0.15
	$0.90 in bins
Loading to wagons	0.01
Hauling to road $\frac{3}{4}$	0.22
Spreading	0.06
Rolling	0.08
	$1.27
Consolidation	0.38
	$1.65
Screenings No. 2 and Bit	3.10
Profit	0.90
Overhead	0.30
Estimate	$5.95
Say $6.00	

No. 2 Screenings and Bitumen. Note. There should be enough local screenings for about $\frac{2}{3}$ of the top course. Use imported for the balance.

Cost 0.45 cu. yd. screenings and No. 2 at bin	$0.40
Hauling $\frac{3}{4}$ mile	0.10
Spreading	0.12
Manipulation 21 gals. bitumen @ $1\frac{1}{2}$¢	0.32
Cost 21 gals. bitumen on road @ $8\frac{1}{2}$¢	1.82
	$2.74

IMPORTED SCREENINGS AND NO. 2

Cost 0.45 cu. yd. f. o. b. switch @ $1.25 per ton	$0.70
Unloading	0.05
Hauling 3 miles	0.90
Spreading	0.12
Manipulation 21 gals. Bit. @ $1\frac{1}{2}$¢	0.32
Cost 21 gals. bitumen on road @ $8\frac{1}{2}$¢	1.80
	$3.89

Average price $3.10

IMPORTED LIMESTONE WATERBOUND MAC. STA. 0–133

Materials

4400 lbs. of stone @ $1.25 per ton	$2.75
6% profit	0.15
	$2.90

Labor

Unloading	$0.10
Hauling 3 miles @ $0.25	0.75
Spreading	0.08
Rolling and puddling	0.10
	$1.03
Consolidation 0.3	0.31
	$1.34
Screenings	0.55
20% profit	0.38
Overhead	0.30
Materials	2.90
Estimate	$5.47

Screenings

Unloading	$0.05
Hauling 3 mi.	0.40
Spreading and brooming	0.10
	$0.55

IMPORTED LIMESTONE WATERBOUND MAC. STA. 133 TO 450

Materials	$2.90
Labor	
Unloading	$0.10
Hauling 90 sta. $1\frac{3}{4}$ miles	0.55
Spreading	0.08
Rolling and puddling	0.10
	$0.83
Consolidation	0.25
	$1.08
Screenings	0.45
20% profit	0.30
Overhead	0.30
Materials	2.90
Estimate	$5.03

Say $5.00

Screenings

Unloading	$0.05
Hauling $1\frac{3}{4}$ miles	0.30
Spreading and Brooming	0.10
	$0.45

Imported Limestone Bituminous Macadam Sta. 133 to 450

Materials

4200 lbs. @ $1.25 f. o. b. per ton	$2.62
6% profit	0.15
	$2.77

Labor

Unloading	$0.10
Hauling	0.55
Spreading	0.08
Rolling	0.08
	$0.81
Consolidation 0.3	0.24
	$1.05
Screenings and Bit.	2.52
20% profit	0.70
Overhead	0.30
Materials	2.77
Estimate	$7.34

Screenings, No. 2 and Bitumen

Unloading	$0.05
Hauling	0.25
Spreading and brooming	0.12
21 gals. Bit. A @ $8\frac{1}{2}$¢	1.78
Manipulation of Bitumen	0.32
	$2.52

Imported Limestone Bottom Sta. 200 to 280

Materials

3200 lbs. stone @ $1.25 per ton	$2.00
Profit	0.10
Total Materials	$2.10

Labor

Unloading	$0.10
Hauling average distance, 20 sta.	0.15
Spreading	0.06
Rolling	0.05
	$0.36
Consolidation 0.3	0.11
	$0.47
Filler	0.20
	$0.67
20% profit	0.13
Overhead	0.30
Materials	2.10
	$3.20

LOCAL STONE MAC. BOTTOM STA. 280 TO 350

Stone in fences	$0.10
Sledging	0.05
Loading	0.15
Hauling to crusher 1 mile	0.35
Crushing	0.12
Cost in bins	$0.77
Loading to wagons	0.01
Haul to road 0.7 mile	0.22
Spreading	0.06
Rolling	0.05
	$1.11
Consolidation 0.3	0.33
	$1.44
Filler	0.20
	$1.64
20% profit	0.33
Overhead	0.30
Say $2.30	$2.27

LAKE GRAVEL BOTTOM STA. 350 TO 450

Assume $\frac{1}{3}$ material from Manitou Beach.
" $\frac{2}{3}$ " from beach $1\frac{1}{2}$ miles north of Sta. 350.

SELECTED BEACH RUN OF GRAVEL

Cost on beach	$0.10
Loading	0.15
Hauling average 2 miles	0.70
Spreading	0.05
Rolling	0.04
Loam and Flushing	0.05
	$1.09
Consolidation 0.2	0.22
	$1.31
20% profit	0.26
Overhead	0.30
Say $1.90	$1.87

Approximate Cost Estimates

Design No. 1.

Sec. No. 1 — 12′ wide 6″ sub-base 3″ bit. mac. local top 6′ of stone on shoulders. Treated with Tarvia B or No. 4 Road Oil. Sta. 0–133.

" No. 2 — 14′ wide 5″ local mac. bot. 3″ waterbound imported lime-stone top. Treated with Tarvia B. 4′ stone on shoulders. Sta. 133 to 200.

" No. 3 — 14′ wide 5″ imported bottom; same top as from Sta. 133 to 200 Sta. 200 to 260. 4′ stone on shoulders.

" No. 4 — 12′ wide 5″ imported bottom 3″ water imported top Tarvia B. 6′ of stone on shoulders Sta. 260 to 280.

" No. 5 — 12′ wide 5″ local mac. bottom 3″ water imported top Tarvia B. 6′ stone on shoulders. Sta. 280–310.

" No. 6 { 16′ wide 9″ sub-base bottom 3″ water mac. top Tarvia B. No stone on shoulders. Sta. 310 to 335.

" No. 7 { 12′ wide 5″ local mac. bottom 3″ water mac. top Tarvia B. 6′ of stone on shoulders. Sta. 335 to 350.

" No. 8 { 12′ wide 5″ lake gravel bottom 3″ water mac. top Tarvia B. 6′ of gravel or stone on shoulders. Sta. 350 to 450.

		Approx. Amount
Sec. 1.	*Sta. 0 to 133*	
	3000 cu. yds. 6″ Sub-base Bottom @ $1.50	$ 4500.00
	1500 " " 3″ Bit. Mac. (Local) Top @ $6.00	9000.00
	730 " " Stone on Shoulders (loose) @ $1.50	1100.00
	3500 gals. Tarvia B on Stone Shoulders @ $0.08	280.00
Sec. 2.	*Sta. 133 to 200*	
	1450 cu. yds. 5″ Local Mac. Bottom @ $2.50	3625.00
	870 " " 3″ Imported Waterbound Top @ $5.00	4350.00
	270 " " Stone on Shoulder @ $1.50	405.00
	5400 gals. Tarvia B @ $0.08	430.00
Sec. 3.	*Sta. 200 to 260*	
	1300 cu. yds. 5″ Imported Bottom @ $3.20	$4150.00
	780 " " 3″ " Water Mac. Top @ $5.00	3900.00
	240 " " Stone on Shoulders @ $1.50	360.00
	4800 gals. Tarv'a B @ $0.08	385.00
Sec. 4.	*Sta. 260 to 280*	
	370 cu. yds. 5″ Imported Bottom @ $3.20	$ 1185.00
	230 " " 3″ " Water Mac. Top @ $5.00	1150.00
	110 " " Stone on Shoulders @ $1.50	165.00
	1600 gals. Tarvia B @ $0.08	130.00
Sec. 5.	*Sta. 280 to 310*	
	560 cu. yds. 5″ Local Bottom @ $2.30	$ 1290.00
	340 " " 3″ Water Mac. Top @ $5.00	1700.00
	170 " " Stone on Shoulders @ $1.50	255.00
	2400 gals. Tarvia B @ $0.08	190.00
Sec. 6.	*Sta. 310 to 335*	
	1130 cu. yds. 9″ Sub-base Bottom @ $1.75	$ 1980.00
	380 " " 3″ Water Mac. Top @ $5.00	1900.00
	1800 gals. Tarvia B @ $0.08	145.00
Sec. 7.	*Sta. 335 to 350*	
	280 cu. yds. 5″ Local Bottom @ $2.30	$ 645.00
	170 " " 3″ Water Mac. Top @ $5.00	850.00
	80 " " Stone on Shoulders @ $1.50	120.00
	1200 gals Tarvia B @ $0.08	95.00
Sec. 8.	*Sta. 350 to 450*	
	1900 cu. yds. 5″ Lake Gravel Bottom @ $1.90	$ 3600.00
	1150 " " 3″ Water Mac. Top @ $5.00	5750.00
	550 " " Gravel on Shoulders @ $1.50	825.00
	8000 gals. Tarvia B @ $0.08	640.00
	Totals	$55100.00
	Items other than Metal	38450.00
	Total Estimate	$93550.00

Design No. 2. Same widths and foundation construction as Design No. 1 except that a $2\frac{1}{2}''$ Imported Limestone Bituminous Macadam is substituted for the 3″ Waterbound Top treated with Tarvia B.

Cost of 3″ Water Mac. Top Design No. 1	$19,600
" " Tarvia B on Mac. Top Design No. 1	1,500
Total	$21,100
Cost of $2\frac{1}{2}''$ Bit. Mac. Top	23,800
Increased Cost Design No. 2 over No. 1	$ 2,700

Design No. 3. 16′ road entire distance local bottom Sta. 0 to 200 and 280 to 450 and imported bottom Sta. 200 to 280 with 3″ Imported Waterbound Macadam treated with 0.4 gal. Tarvia B or 0.25 gal. No. 4 Road Oil.

9200 cu. yds. local bottom 5″ thick @ $2.25	$ 20,700
1970 " " imported bottom 5″ thick @ $3.20	6,300
6700 " " " Top 3″ thick @ $5.10	34,200
32000 gals. Tarvia B @ $0.08	2,560
	$ 63,760
Items other than metalling	38,450
	$102,210

Design No. 4. Substitute a $2\frac{1}{2}''$ Bit. Mac. Top for the 3″ Waterbound Top of Design No. 3. This increases the cost approx. $4000.

Signed

Designing Engineer.

Maximum gradients for the various types of pavement are as follows:

Wooden block	2%
Asphalt block	4%
Brick	5%
Concrete	5%
Bituminous macadam with flush or squeegee coat	4%
(In sandy country, six per cent when coarse sand is sprinkled on surface.)	
Bituminous macadam without squeegee	8%
Waterbound macadam	8%
"Hillside" brick	12%
Stone block with open joints	12%

Shrinkage of Earthwork.

We have made no mention heretofore of the shrinkage of earth cut when placed in fill. This is an important factor of an economical grading design.

Trautwine states that for railroad work it takes

1.08 cu. yds. gravel or sand excavation to make 1 cu. yd. embankment.

1.10 cu. yds. clay excavation to make 1 cu. yd. embankment.

1.12 cu. yds. loam excavation to make 1 cu. yd. embankment.

1.15 cu. yds. vegetable surface soil excavation to make 1 cu. yd. embankment.

The quantities 1.08 cu. yds. gravel, etc., refer to the volume occupied by the material before removal.

Trautwine also states that in loosening earth and loading into wagons or cars 1 cu. yd. of earth swells about one-fifth and measures loose practically 1.2 cu. yds.

These values, however, cannot be used in roadwork, as a certain percentage of the excavation is sod or vegetable matter that is not suitable for embankment and must be wasted.

This waste material raises the percentage of cut necessary to make the fill.

The correct ratio for roadwork has been a source of contention among engineers, and we believe that the use of too high a value has resulted in a needless waste of thousands of dollars during the last five years in New York State alone.

Under this head it may be stated that on several roads under the supervision of W. G. Harger, a careful study of this point

was made, taking unusual care with the original and final cross-sections, the plotting and planimeter work, and it was found that for the cases investigated, the ratio of cut to fill varied from 1.15 in heavy cuts to 1.27 in light skimming work.

It is the general opinion among engineers of Division 5, N. Y. S. Dept. of Highways, that the percentage formerly used (namely 1.35) is too high. In nearly all cases where the work was at all heavy, a large excess of dirt had to be wasted. There have been some roads designed on a basis of 1.35 where more dirt was needed, but in the authors' opinion this was due to discrepancies in the field or office work or by allowing the contractor to use the roadbed excavation for filler or concrete material. If the soil encountered is suitable for such purposes, it is plainly up to the contractor to furnish other material for the places excavated.

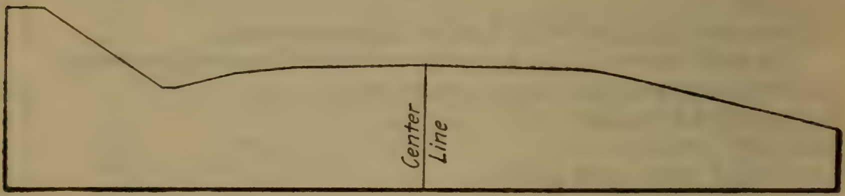


Fig. 61.— Transparent Templet for Use on Cross-Sections Giving Finished Shape of Road

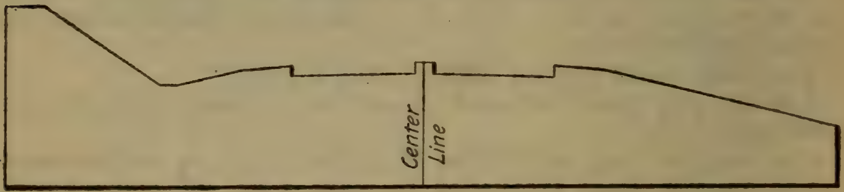


Fig. 62.— Transparent Templet with Stone Trench Cut; Saves Time in Drawing in Sections for Figuring Cut and Fill

The authors believe that the following ratios will be satisfactory for ordinary cases:

Table 32

Light skimming work, large amount of heavy sod	1.35
Light skimming work, considerable sod	1.30
Light skimming work, not much sod	1.25
Medium work	1.20
Heavy work	1.15

Trautwine's earth ratios are correct where earth borrow is obtained from a pit.

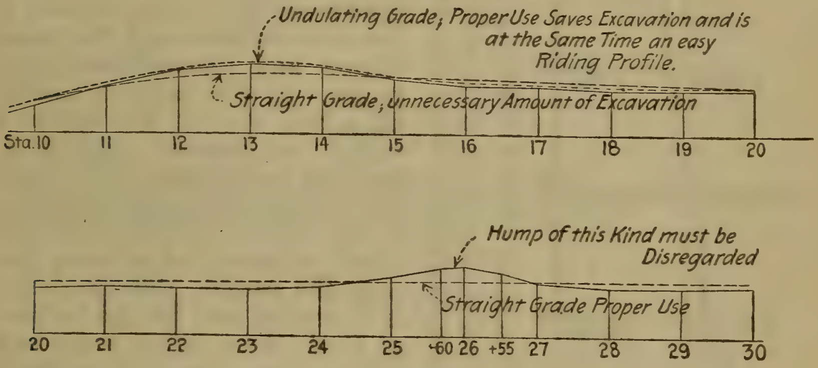
Trautwine states that 1.0 cu. yd. of solid rock, when broken up, will make 1.66 to 1.75 cu. yds. of rock fill.

In this statement he assumes that the fill is made of stone alone

and that the voids are not filled. In most roadwork, the small quantities of rock encountered are dumped in with the earth as embankment, and as the voids are all filled with earth it is evident that 1 cu. yd. of rock will make only 1 cu. yd. of fill; however, if a large unmixed stone fill is made, his ratio holds.

The discussion of these ratios has been carried out to some length because we believe it is one of the points that illustrate the advantage of careful engineering. Several of the New York State plans, the cost of which has ranged from $100 to $200 per mile, have been revised with this end in view; the revision costing an additional $15 to $30 per mile, with a resultant saving in construction cost of from $200 to $300 per mile.

The use of a rolling grade was recommended in the chapter on Grades. The designer is cautioned, however, not to carry this to extremes as there are many short, small hummocks which must be disregarded if a reasonably good profile is to be obtained. Fig. 62 A indicates a proper and improper use of an undulating profile.



Illustrating Proper Use of Straight and Undulating Grades

FIG. 62 A

Templets.

For the convenience of the designer in drawing the shape of the finished road on the cross-sections, a number of transparent composition templets are made, cut to proper scale, representing the different shaped sections to be used. See Figs. 61 and 62.

Economical Grade Line.

On page 13, the most economical grading conditions were mentioned. A convenient method of laying a grade line that will approximate these conditions is as follows: take the case of determining an economical profile for a road from station 11 to station 16, where the grade can be placed at any desired elevation (see page 13). Place the adopted templet on each cross-section so that the cut will just make the fill (this position is

estimated) and note the elevation of the center line of the proposed finished road for this position of the templet; mark this elevation on the profile for each section between stations 11 and 16; to connect these points would give the most economical grade line, but this can rarely be done with a resulting smooth profile. The adopted grade is obtained by drawing in a smooth grade line, that averages the elevations of these points and varies in elevation above or below them as little as possible.

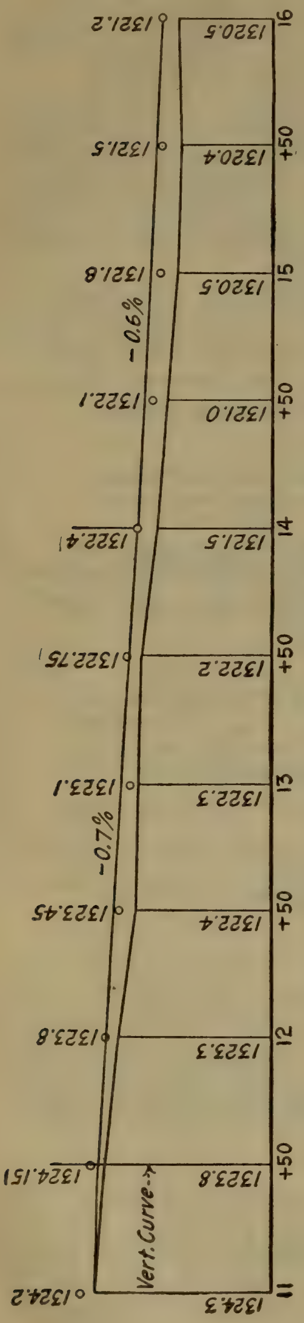


FIG. 63. — Sample Profile illustrating Method of Placing an Economical Grade Line

NOTE. — The small circles show the elevation of grade at each section that would make the proposed cut just make the proposed fill at that section.

The adopted grade elevation at each station is then figured, the shape of the finished road drawn on the cross-sections at these elevations, and the excavation and embankment computed. If the ratio of cut to fill is not correct, the grade is raised or lowered slightly to produce the desired ratio. This method is illustrated in Fig. 63.

For each stretch of road where economy of grading governs the profile, this procedure is repeated, and for the sections of road where other considerations govern, the grade is placed at the required elevation and the borrow, waste, or overhaul figured.

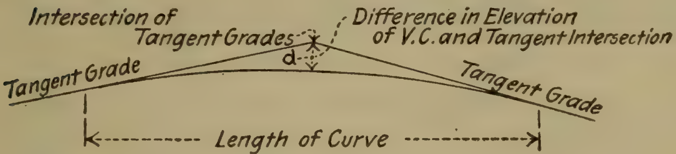
To obtain a smooth grade line vertical curves are used at the intersection of the different tangent rates of grade. Vertical curves are not usually used where the difference in rates of grade is less than ½ per cent.

For the final plans these vertical curve elevations may be computed by the following formulæ, but for the trial grade line they can be scaled from the profile, drawing in the curve by means of a regular curve templet, with which all modern offices are equipped.

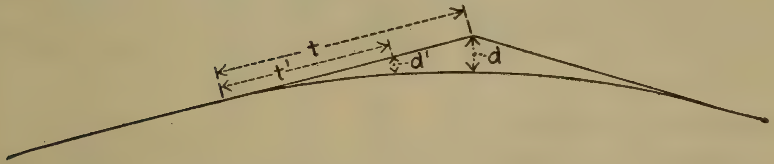
V. C. Formulæ:

Formula A. Difference in elevation at Center of Curve.

d expressed in feet $= \frac{1}{8}$ (Algebraic difference of the tangent grades expressed in feet per 100) $\times$ (length of curve expressed in stations of 100′).



FORMULA A

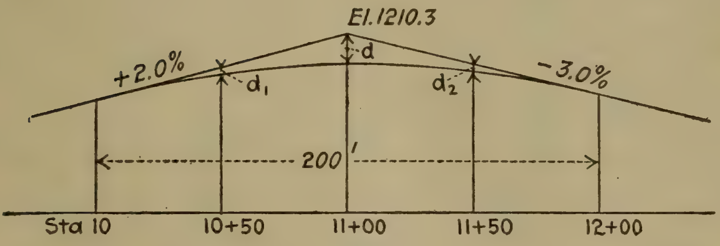


FORMULA B

Formula B. Intermediate differences of Elevations between tangent grades and points on vertical curve.

$$d' : d :: t'^2 : t^2$$

$$d' = \frac{dt'^2}{t^2}$$



EXAMPLE OF VERTICAL CURVE COMPUTATION

It is required to figure the vertical curve elevations for a vertical curve 200′ long between tangent grades of $+ 2.0\%$ and $- 3.0\%$ meeting at station $11 + 00$ at an elevation of 1210.3.

First, find the middle correction d: use formula A.

$$d = \tfrac{1}{8}\,(2.0 - (-3.0)) \times (2)$$
$$d = \tfrac{1}{8}\,(5) \times (2) = \tfrac{10}{8} = 1.25'$$

Second, determine the corrections d_1 and d_2; use formula B.

$$d_1 = \frac{dt'^2}{t^2} = 1.25\frac{50^2}{100^2} = 1.25 \times \tfrac{1}{4} = 0.31 \text{ feet}$$

$$d_2 = 1.25\frac{50^2}{100^2} = 0.31 \text{ feet.}$$

Third, determine the elevation of the tangent grades at 10 + 50 and 11 + 50.

Fourth, subtract the *V.C.* corrections d_1, d, and d_2 from these tangent grades at 10 + 50, 11 + 00 and 11 + 50.

VERTICAL CURVE ELEVATIONS

Sta. 10 + 50 =	Tangent	Elev.	1209.3 − 0.31	= 1208.99
" 11 + 00 =	"	"	1210.3 − 1.25	= 1209.05
" 11 + 50 =	"	"	1208.8 − 0.31	= 1208.49

The following table, No. 33, is useful for draftsmen in picking out the correct curve to use in inking in the vertical curves. This table is compiled for a horizontal scale of 1″ = 50′, and a vertical scale of 1″ = 10′. For other scales a similar table can be constructed.

Explanation of Table 33.

Suppose it is required to pick out the correct curve templet to draw in a vertical curve 300′ long between two tangent grades having an algebraic difference of 5 per cent (say a + 2.0 per cent grade and a − 3.0 per cent grade). On the line opposite 5.0 in column 1 representing the algebraic difference of rate, pick out the value 24 in the column headed 300′ curve; this means that a curve having a radius of 24 inches will fit the conditions. This curve can be found easily from the collection of curve templets which have been previously marked with their radii in inches.

The limit of sight due to vertical curves is shown in Table 34.

Table 34 gives the distance ahead that a driver can see on a straight road, assuming that his eye is 6 feet above the road, for vertical curves of 200 feet, 150 feet, and 100 feet long between grades having a large difference of rate.

Example. Suppose a plus 5 percent grade meets a minus 7 per cent grade and that it is desired to put in the minimum length curve that will allow a sight ahead of 300 feet. The difference in gradient is 5 + 7 = 12 per cent. From table 34, opposite 12 per cent, we can readily pick the length required; it will be about 170 feet and 200 feet would probably be used. It is rare that the sight distance governs in the selection of length of curve.

Placing the Templets and Planimetering the Areas.

After the trial grade line has been placed the center line elevations of the proposed finished road are figured for each point on the profile where cross-sections have been taken and the section selected is drawn on the original cross-sections at these elevations, using the templets mentioned above.

Because it is comparatively easy to make a mistake of one

TABLE 33. TABLE OF RADII FOR PLOTTING VERTICAL CURVES ON PROFILES

Algebraic Diff.	100′ Curve Rad.	200′ Curve Rad.	300′ Curve Rad.	400′ Curve Rad.
1.0	40	80	120	160
1.2	33	67	100	132
1.4	29	57	85	116
1.6	25	50	75	100
1.8	22	44	65	88
2.0	20	40	60	80
2.2	18	36	55	72
2.4	16½	33	50	66
2.6	15½	30	46	62
2.8	14½	29	43	58
3.0	13½	27	40	54
3.2	12½	25	37	50
3.4	12	23	35	48
3.6	11	22	33	44
3.8	10½	21	32	42
4.0	10	20	30	40
4.5	9	18	27	36
5.0	8	16	24	32
5.5	7	14½	22	28
6.0	6½	13½	20	26
7.0	6	11½	17	24
8.0	5	10	16	20
9.0	4½	9	13½	18
10.0	4	8	12	16
11.0	3½	7	11	14½
12.0	3½	6½	10	13½
13.0	3	6	9	12½
14.0	3	5½	8½	11½

TABLE 34

Difference in Rate of Grades	Sight Distance for 200 ft. V. C.	Sight Distance for 150 ft. V. C.	Sight Distance for 100 ft. V. C.
8%	—	—	370 feet
10%	355 feet	315 feet	290 "
12%	320 "	290 "	260 "
14%	290 "	260 "	230 "
16%	260 "	230 "	210 "

foot or five feet in elevation, the elevation of new grade, as shown by the position of the templet, should be checked from the profile before computing the cuts and fills.

Because of the small, irregular shape of these areas it is not possible to compute them arithmetically and the areas are determined by planimeters. Great care must be exercised if the work is to be reliable; a double run is made and the second run should be twice the first area. A certain limit of error in the second area is adopted.[1] This method is sufficiently accurate for preliminary estimating. On final estimate work, where the payment for earth excavation depends on the planimeter work, a satisfactory method is to have two men, using separate planimeters, compute the areas independently without any knowledge of each other's result. If the amount of excavation as figured separately varies more than 2 per cent, a third run is made.

The reason that it is difficult to get accurate planimeter results is that the work is monotonous, confining, and hard on the eyes, and the tendency is toward carelessness unless the men know that their work is being checked.

The temptation is strong to make the second reading equal twice the first, and unless some such method is used to check up, small errors will be passed over.

As a matter of interest three miles of planimeter work, checked in this manner, was examined to see the average difference in areas, where two careful men using different planimeters computed their results separately.

The sections used were plotted 1″ = 5′; areas read to nearest 0.1 sq. ft.

The average percentage of difference for single areas were

1.	Small areas below 10 sq. ft.	......per cent of difference	5%
2.	" " 10 to 30 " "	...... " " " "	2%
3.	Areas above 30 " "	...... " " " "	1%

However, these differences for single areas compensate, as some are above and some below the mean value, and computing the two separate results for the three miles gave the following result.

Percentage differences for work of two men for three miles, showing the reduction of error due to compensation.

1.	Small areas below 10 sq. ft.	....per cent of difference	1.0 %
2.	" " 10 to 30 " "	.... " " " "	0.5 %
3.	Areas above 30 " "	.... " " " "	0.05 %

The average excavation per mile will run about 3,000 cu. yds., which means the average area of cut is about 16 sq. ft.

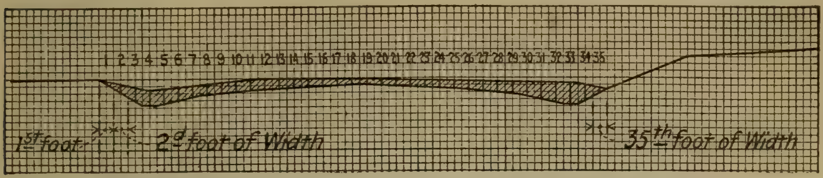
This comes under the second division and makes the probable error of final estimate planimeter work sufficiently close for all practical purposes.

Areas by measuring the depth of cut or fill at intervals of one foot across the section.

It is often necessary for the field men to make a change in grade or alignment, and the following method of estimating section areas

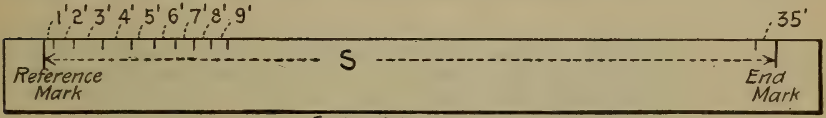
[1] A satisfactory rule has been to allow a difference of 0.4 sq. ft. for areas up to 50 sq. ft., and 1.0 sq. ft. error above 50 sq. ft.

is convenient when no planimeter is available. The method is illustrated in the figures shown below:—



Measure the depth of the cutting on vertical No. 1. Call this depth 1′. It can be readily seen that this depth is the average depth for the first foot of the cross section, and if multiplied by one foot equals the area of the first foot of the section. In like manner measure the depth of the section on vertical No. 2. This is the average depth of the second foot of the section, and multiplied by one foot equals the area of the second foot of the section. If the sum of the depths 1′, 2′, 3′, etc., is obtained for the entire width of the section it is evident that the sum must equal the area of the section.

This summation can readily be made graphically as shown below by marking off on the edge of a piece of paper the successive depths.



Strip of Paper

Scale the distance from the reference mark to the end mark, using the same scale by which the cross section is plotted and the area of the section is obtained. This method is as reliable as planimeter work, but is necessarily slower.

Computation of Earthwork.

Earthwork is usually computed from the planimeter results by the method of end areas; where 50-ft. sections are used the following table is convenient.

Explanation of Table 35.

Suppose the area of excavation at, say, station 22 + 00 is 30.6 sq. ft.; suppose the excavation area at station 22 + 50 is 20.1 sq. ft. To get the number of cubic feet of excavation from station 22 + 00 to 22 + 50 add 30.6 + 20.1 = 50.7. In Table 35 an area of 50.7 gives an excavation quantity of 1267.5 cu. ft. Where the normal cross-section interval is 50 ft. this table is a great time-saver.

Table 36 is convenient in changing cubic feet to cubic yards.

Table 37 is convenient for preliminary estimates, as it gives the cubic yards directly for the sum of the end areas in square feet. It, however, is not figured exactly and is not suitable for final estimate work.

TABLE 35. VOLUME OF 50-FT. SECTIONS IN CUBIC FEET FOR SUM OF END AREAS

COMPILED BY J. H. HUBER, ASSISTANT ENGINEER, BUFFALO, N.Y.

Sum of End Areas Sq. Ft.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	—	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
1	25.0	27.5	30.0	32.5	35.0	37.5	40.0	42.5	45.0	47.5
2	50.0	52.5	55.0	57.5	60.0	62.5	65.0	67.5	70.0	72.5
3	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5
4	100.0	102.5	105.0	107.5	110.0	112.5	115.0	117.5	120.0	122.5
5	125.0	127.5	130.0	132.5	135.0	137.5	140.0	142.5	145.0	147.5
6	150.0	152.5	155.0	157.5	160.0	162.5	165.0	167.5	170.0	172.5
7	175.0	177.5	180.0	182.5	185.0	187.5	190.0	192.5	195.0	197.5
8	200.0	202.5	205.0	207.5	210.0	212.5	215.0	217.5	220.0	222.5
9	225.0	227.5	230.0	232.5	235.0	237.5	240.0	242.5	245.0	247.5
10	250.0	252.5	255.0	257.5	260.0	262.5	265.0	267.5	270.0	272.5
11	275.0	277.5	280.0	282.5	285.0	287.5	290.0	292.5	295.0	297.5
12	300.0	302.5	305.0	307.5	310.0	312.5	315.0	317.5	320.0	322.5
13	325.0	327.5	330.0	332.5	335.0	337.5	340.0	342.5	345.0	347.5
14	350.0	352.5	355.0	357.5	360.0	362.5	365.0	367.5	370.0	372.5
15	375.0	377.5	380.0	382.5	385.0	387.5	390.0	392.5	395.0	397.5
16	400.0	402.5	405.0	407.5	410.0	412.5	415.0	417.5	420.0	422.5
17	425.0	427.5	430.0	432.5	435.0	437.5	440.0	442.5	445.0	447.5
18	450.0	452.5	455.0	457.5	460.0	462.5	465.0	467.5	470.0	472.5
19	475.0	477.5	480.0	482.5	485.0	487.5	490.0	492.5	495.0	497.5
20	500.0	502.5	505.0	507.5	510.0	512.5	515.0	517.5	520.0	522.5
21	525.0	527.5	530.0	532.5	535.0	537.5	540.0	542.5	545.0	547.5
22	550.0	552.5	555.0	557.5	560.0	562.5	565.0	567.5	570.0	572.5
23	575.0	577.5	580.0	582.5	585.0	587.5	590.0	592.5	595.0	597.5
24	600.0	602.5	605.0	607.5	610.0	612.5	615.0	617.5	620.0	622.5
25	625.0	627.5	630.0	632.5	635.0	637.5	640.0	642.5	645.0	647.5
26	650.0	652.5	655.0	657.5	660.0	662.5	665.0	667.5	670.0	672.5
27	675.0	677.5	680.0	682.5	685.0	687.5	690.0	692.5	695.0	697.5
28	700.0	702.5	705.0	707.5	710.0	712.5	715.0	717.5	720.0	722.5
29	725.0	727.5	730.0	732.5	735.0	737.5	740.0	742.5	745.0	747.5
30	750.0	752.5	755.0	757.5	760.0	762.5	765.0	767.5	770.0	772.5
31	775.0	777.5	780.0	782.5	785.0	787.5	790.0	792.5	795.0	797.5
32	800.0	802.5	805.0	807.5	810.0	812.5	815.0	817.5	820.0	822.5
33	825.0	827.5	830.0	832.5	835.0	837.5	840.0	842.5	845.0	847.5
34	850.0	852.5	855.0	857.5	860.0	862.5	865.0	867.5	870.0	872.5
35	875.0	877.5	880.0	882.5	885.0	887.5	890.0	892.5	895.0	897.5
36	900.0	902.5	905.0	907.5	910.0	912.5	915.0	917.5	920.0	922.5
37	925.0	927.5	930.0	932.5	935.0	937.5	940.0	942.5	945.0	947.5
38	950.0	952.5	955.0	957.5	960.0	962.5	965.0	967.5	970.0	972.5
39	975.0	977.5	980.0	982.5	985.0	987.5	990.0	992.5	995.0	997.5
40	1000.0	1002.5	1005.0	1007.5	1010.0	1012.5	1015.0	1017.5	1020.0	1022.5
41	1025.0	1027.5	1030.0	1032.5	1035.0	1037.5	1040.0	1042.5	1045.0	1047.5
42	1050.0	1052.5	1055.0	1057.5	1060.0	1062.5	1065.0	1067.5	1070.0	1072.5
43	1075.0	1077.5	1080.0	1082.5	1085.0	1087.5	1090.0	1092.5	1095.0	1097.5
44	1100.0	1102.5	1105.0	1107.5	1110.0	1112.5	1115.0	1117.5	1120.0	1122.5
45	1125.0	1127.5	1130.0	1132.5	1135.0	1137.5	1140.0	1142.5	1145.0	1147.5
46	1150.0	1152.5	1155.0	1157.5	1160.0	1162.5	1165.0	1167.5	1170.0	1172.5
47	1175.0	1177.5	1180.0	1182.5	1185.0	1187.5	1190.0	1192.5	1195.0	1197.5
48	1200.0	1202.5	1205.0	1207.5	1210.0	1212.5	1215.0	1217.5	1220.0	1222.5
49	1225.0	1227.5	1230.0	1232.5	1235.0	1237.5	1240.0	1242.5	1245.0	1247.5
50	1250.0	1252.5	1255.0	1257.5	1260.0	1262.5	1265.0	1267.5	1270.0	1272.5

NOTE. — For volumes larger than those given, use figures in the table, moving decimal point one place to the right and add proportional part.

TABLE 35. VOLUME OF 50-FT. SECTIONS IN CUBIC FEET FOR SUM OF END AREAS. — *Continued*

COMPILED BY J. H. HUBER, ASSISTANT ENGINEER, BUFFALO, N.Y.

Sum of End Areas Sq. Ft.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
50	1250.0	1252.5	1255.0	1257.5	1260.0	1262.5	1265.0	1267.5	1270.0	1272.5
51	1275.0	1277.5	1280.0	1282.5	1285.0	1287.5	1290.0	1292.5	1295.0	1297.5
52	1300.0	1302.5	1305.0	1307.5	1310.0	1312.5	1315.0	1317.5	1320.0	1322.5
53	1325.0	1327.5	1330.0	1332.5	1335.0	1337.5	1340.0	1342.5	1345.0	1347.5
54	1350.0	1352.5	1355.0	1357.5	1360.0	1362.5	1365.0	1367.5	1370.0	1372.5
55	1375.0	1377.5	1380.0	1382.5	1385.0	1387.5	1390.0	1392.5	1395.0	1397.5
56	1400.0	1402.5	1405.0	1407.5	1410.0	1412.5	1415.0	1417.5	1420.0	1422.5
57	1425.0	1427.5	1430.0	1432.5	1435.0	1437.5	1440.0	1442.5	1445.0	1447.5
58	1450.0	1452.5	1455.0	1457.5	1460.0	1462.5	1465.0	1467.5	1470.0	1472.5
59	1475.0	1477.5	1480.0	1482.5	1485.0	1487.5	1490.0	1492.5	1495.0	1497.5
60	1500.0	1502.5	1505.0	1507.5	1510.0	1512.5	1515.0	1517.5	1520.0	1522.5
61	1525.0	1527.5	1530.0	1532.5	1535.0	1537.5	1540.0	1542.5	1545.0	1547.5
62	1550.0	1552.5	1555.0	1557.5	1560.0	1562.5	1565.0	1567.5	1570.0	1572.5
63	1575.0	1577.5	1580.0	1582.5	1585.0	1587.5	1590.0	1592.5	1595.0	1597.5
64	1600.0	1602.5	1605.0	1607.5	1610.0	1612.5	1615.0	1617.5	1620.0	1622.5
65	1625.0	1627.5	1630.0	1632.5	1635.0	1637.5	1640.0	1642.5	1645.0	1647.5
66	1650.0	1652.5	1655.0	1657.5	1660.0	1662.5	1665.0	1667.5	1670.0	1672.5
67	1675.0	1677.5	1680.0	1682.5	1685.0	1687.5	1690.0	1692.5	1695.0	1697.5
68	1700.0	1702.5	1705.0	1707.5	1710.0	1712.5	1715.0	1717.5	1720.0	1722.5
69	1725.0	1727.5	1730.0	1732.5	1735.0	1737.5	1740.0	1742.5	1745.0	1747.5
70	1750.0	1752.5	1755.0	1757.5	1760.0	1762.5	1765.0	1767.5	1770.0	1772.5
71	1775.0	1777.5	1780.0	1782.5	1785.0	1787.5	1790.0	1792.5	1795.0	1797.5
72	1800.0	1802.5	1805.0	1807.5	1810.0	1812.5	1815.0	1817.5	1820.0	1822.5
73	1825.0	1827.5	1830.0	1832.5	1835.0	1837.5	1840.0	1842.5	1845.0	1847.5
74	1850.0	1852.5	1855.0	1857.5	1860.0	1862.5	1865.0	1867.5	1870.0	1872.5
75	1875.0	1877.5	1880.0	1882.5	1885.0	1887.5	1890.0	1892.5	1895.0	1897.5
76	1900.0	1902.5	1905.0	1907.5	1910.0	1912.5	1915.0	1917.5	1920.0	1922.5
77	1925.0	1927.5	1930.0	1932.5	1935.0	1937.5	1940.0	1942.5	1945.0	1947.5
78	1950.0	1952.5	1955.0	1957.5	1960.0	1962.5	1965.0	1967.5	1970.0	1972.5
79	1975.0	1977.5	1980.0	1982.5	1985.0	1987.5	1990.0	1992.5	1995.0	1997.5
80	2000.0	2002.5	2005.0	2007.5	2010.0	2012.5	2015.0	2017.5	2020.0	2022.5
81	2025.0	2027.5	2030.0	2032.5	2035.0	2037.5	2040.0	2042.5	2045.0	2047.5
82	2050.0	2052.5	2055.0	2057.5	2060.0	2062.5	2065.0	2067.5	2070.0	2072.5
83	2075.0	2077.5	2080.0	2082.5	2085.0	2087.5	2090.0	2092.5	2095.0	2097.5
84	2100.0	2102.5	2105.0	2107.5	2110.0	2112.5	2115.0	2117.5	2120.0	2122.5
85	2125.0	2127.5	2130.0	2132.5	2135.0	2137.5	2140.0	2142.5	2145.0	2147.5
86	2150.0	2152.5	2155.0	2157.5	2160.0	2162.5	2165.0	2167.5	2170.0	2172.5
87	2175.0	2177.5	2180.0	2182.5	2185.0	2187.5	2190.0	2192.5	2195.0	2197.5
88	2200.0	2202.5	2205.0	2207.5	2210.0	2212.5	2215.0	2217.5	2220.0	2222.5
89	2225.0	2227.5	2230.0	2232.5	2235.0	2237.5	2240.0	2242.5	2245.0	2247.5
90	2250.0	2252.5	2255.0	2257.5	2260.0	2262.5	2265.0	2267.5	2270.0	2272.5
91	2275.0	2277.5	2280.0	2282.5	2285.0	2287.5	2290.0	2292.5	2295.0	2297.5
92	2300.0	2302.5	2305.0	2307.5	2310.0	2312.5	2315.0	2317.5	2320.0	2322.5
93	2325.0	2327.5	2330.0	2332.5	2335.0	2337.5	2340.0	2342.5	2345.0	2347.5
94	2350.0	2352.5	2355.0	2357.5	2360.0	2362.5	2365.0	2367.5	2370.0	2372.5
95	2375.0	2377.5	2380.0	2382.5	2385.0	2387.5	2390.0	2392.5	2395.0	2397.5
96	2400.0	2402.5	2405.0	2407.5	2410.0	2412.5	2415.0	2417.5	2420.0	2422.5
97	2425.0	2427.5	2430.0	2432.5	2435.0	2437.5	2440.0	2442.5	2445.0	2447.5
98	2450.0	2452.5	2455.0	2457.5	2460.0	2462.5	2465.0	2467.5	2470.0	2472.5
99	2475.0	2477.5	2480.0	2482.5	2485.0	2487.5	2490.0	2492.5	2495.0	2497.5
100	2500.0	2502.5	2505.0	2507.5	2510.0	2512.5	2515.0	2517.5	2520.0	2522.5

PROPORTIONAL PART	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5

TABLE 36. CUBIC FEET AND CUBIC YARDS

0–1350		1350–2700		2700–4050		4050–5400	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
27	1	77	51	2,727	101	77	151
54	2	1,404	2	54	2	4,104	2
81	3	31	3	81	3	31	3
108	4	58	4	2,808	4	58	4
35	5	85	5	35	5	85	5
62	6	1,512	6	62	6	4,212	6
89	7	39	7	89	7	39	7
216	8	66	8	2,916	8	66	8
43	9	93	9	43	9	93	9
70	10	1,620	60	70	110	4,320	160
97	1	47	1	97	1	47	1
324	2	74	2	3,024	2	74	2
51	3	1,701	3	51	3	4,401	3
78	4	28	4	78	4	28	4
405	5	55	5	3,105	5	55	5
32	6	82	6	32	6	82	6
59	7	1,809	7	59	7	4,509	7
86	8	36	8	86	8	36	8
513	9	63	9	3,213	9	63	9
40	20	90	70	40	120	90	170
67	1	1,917	1	67	1	4,617	1
94	2	44	2	94	2	44	2
621	3	71	3	3,321	3	71	3
48	4	98	4	48	4	98	4
75	5	2,025	5	75	5	4,725	5
702	6	52	6	3,402	6	52	6
29	7	79	7	29	7	79	7
56	8	2,106	8	56	8	4,806	8
83	9	33	9	83	9	33	9
810	30	60	80	3,510	130	60	180
37	1	87	1	37	1	87	1
64	2	2,214	2	64	2	4,914	2
91	3	41	3	91	3	41	3
918	4	68	4	3,618	4	68	4
45	5	95	5	45	5	95	5
72	6	2,322	6	72	6	5,022	6
99	7	49	7	99	7	49	7
1,026	8	76	8	3,726	8	76	8
53	9	2,403	9	53	9	5,103	9
80	40	30	90	80	140	30	190
1,107	1	57	1	3,807	1	57	1
34	2	84	2	34	2	84	2
61	3	2,511	3	61	3	5,211	3
88	4	38	4	88	4	38	4
1,215	5	65	5	3,915	5	65	5
42	6	92	6	42	6	92	6
69	7	2,619	7	69	7	5,319	7
96	8	46	8	96	8	46	8
1,323	9	73	9	4,023	9	73	9
50	50	2,700	100	50	150	5,400	200

TABLE 36 — *continued*

5400–6750		6750–8100		8100–9450		9450–10,800	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
5,427	201	77	251	8,127	301	77	351
54	2	6,804	2	54	2	9,504	2
81	3	31	3	81	3	31	3
5,508	4	58	4	8,208	4	58	4
35	5	85	5	35	5	85	5
62	6	6,912	6	62	6	9,612	6
89	7	39	7	89	7	39	7
5,616	8	66	8	8,316	8	66	8
43	9	93	9	43	9	93	9
70	210	7,020	260	70	310	9,720	360
97	1	47	1	97	1	47	1
5,724	2	74	2	8,424	2	74	2
51	3	7,101	3	51	3	9,801	3
78	4	28	4	78	4	28	4
5,805	5	55	5	8,505	5	55	5
32	6	82	6	32	6	82	6
59	7	7,209	7	59	7	9,909	7
86	8	36	8	86	8	36	8
5,913	9	63	9	8,613	9	63	9
40	220	90	270	40	320	90	370
67	1	7,317	1	67	1	10,017	1
94	2	44	2	94	2	44	2
6,021	3	71	3	8,721	3	71	3
48	4	98	4	48	4	98	4
75	5	7,425	5	75	5	10,125	5
6,102	6	52	6	8,802	6	52	6
29	7	79	7	29	7	79	7
56	8	7,506	8	56	8	10,206	8
83	9	33	9	83	9	33	9
6,210	230	60	280	8,910	330	60	380
37	1	87	1	37	1	87	1
64	2	7,614	2	64	2	10,314	2
91	3	41	3	91	3	41	3
6,318	4	68	4	9,018	4	68	4
45	5	95	5	45	5	95	5
72	6	7,722	6	72	6	10,422	6
99	7	49	7	99	7	49	7
6,426	8	76	8	9,126	8	76	8
53	9	7,803	9	53	9	10,503	9
80	240	30	290	80	340	30	390
6,507	1	57	1	9,207	1	57	1
34	2	84	2	34	2	84	2
61	3	7,911	3	61	3	10,611	3
88	4	38	4	88	4	38	4
6,615	5	65	5	9,315	5	65	5
42	6	92	6	42	6	92	6
69	7	8,019	7	69	7	10,719	7
96	8	46	8	96	8	46	8
6,723	9	73	9	9,423	9	73	9
50	250	8,100	300	50	350	10,800	400

TABLE 36 — *continued*

10,800–12,150		12,150–13,500		13,500–14,850		14,850–16,200	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
10,827	401	77	451	13,527	501	177	551
54	2	12,204	2	54	2	14,904	2
81	3	31	3	81	3	31	3
10,908	4	58	4	13,608	4	58	4
35	5	85	5	35	5	85	5
62	6	12,312	6	62	6	15,012	6
89	7	39	7	89	7	39	7
11,016	8	66	8	13,716	8	66	8
43	9	93	9	43	9	93	9
70	410	12,420	460	70	510	15,120	560
97	1	47	1	97	1	47	1
11,124	2	74	2	13,824	2	74	2
51	3	12,501	3	51	3	15,201	3
78	4	28	4	78	4	28	4
11,205	5	55	5	13,905	5	55	5
32	6	82	6	32	6	82	6
59	7	12,609	7	59	7	15,309	7
86	8	36	8	86	8	36	8
11,313	9	63	9	14,013	9	63	9
40	420	90	470	40	520	90	570
67	1	12,717	1	67	1	15,417	1
94	2	44	2	94	2	44	2
11,421	3	71	3	14,121	3	71	3
48	4	98	4	48	4	98	4
75	5	12,825	5	75	5	15,525	5
11,502	6	52	6	14,202	6	52	6
29	7	79	7	29	7	79	7
56	8	12,906	8	56	8	15,606	8
83	9	33	9	83	9	33	9
11,610	430	60	480	14,310	530	60	580
37	1	87	1	37	1	87	1
64	2	13,014	2	64	2	15,714	2
91	3	41	3	91	3	41	3
11,718	4	68	4	14,418	4	68	4
45	5	95	5	45	5	95	5
72	6	13,122	6	72	6	15,822	6
99	7	49	7	99	7	49	7
11,826	8	76	8	14,526	8	76	8
53	9	13,203	9	53	9	15,903	9
80	440	30	490	80	540	30	590
11,907	1	57	1	14,607	1	57	1
34	2	84	2	34	2	84	2
61	3	13,311	3	61	3	16,011	3
88	4	38	4	88	4	38	4
12,015	5	65	5	14,715	5	65	5
42	6	92	6	42	6	92	6
69	7	13,419	7	69	7	16,119	7
96	8	46	8	96	8	46	8
12,123	9	73	9	14,823	9	73	9
50	450	13,500	500	50	550	16,200	600

TABLE 36 — *continued*

16,200–17,550		17,550–18,900		18,900–20,250		20,250–21,600	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
16,227	601	77	651	18,927	701	77	751
54	2	17,604	2	54	2	20,304	2
81	3	31	3	81	3	31	3
16,308	4	58	4	19,008	4	58	4
35	5	85	5	35	5	85	5
62	6	17,712	6	62	6	20,412	6
89	7	39	7	89	7	39	7
16,416	8	66	8	19,116	8	66	8
43	9	93	9	43	9	93	9
70	610	17,820	660	70	710	20,520	760
97	1	47	1	97	1	47	1
16,524	2	74	2	19,224	2	74	2
51	3	17,901	3	51	3	20,601	3
78	4	28	4	78	4	28	4
16,605	5	55	5	19,305	5	55	5
32	6	82	6	32	6	82	6
59	7	18,009	7	59	7	20,709	7
86	8	36	8	86	8	36	8
16,713	9	63	9	19,413	9	63	9
40	620	90	670	40	720	90	770
67	1	18,117	1	67	1	20,817	1
94	2	44	2	94	2	44	2
16,821	3	71	3	19,521	3	71	3
48	4	98	4	48	4	98	4
75	5	18,225	5	75	5	20,925	5
16,902	6	52	6	19,602	6	52	6
29	7	79	7	29	7	79	7
56	8	18,306	8	56	8	21,006	8
83	9	33	9	83	9	33	9
17,010	630	60	680	19,710	730	60	780
37	1	87	1	37	1	87	1
64	2	18,414	2	64	2	21,114	2
91	3	41	3	91	3	41	3
17,118	4	68	4	19,818	4	68	4
45	5	95	5	45	5	95	5
72	6	18,522	6	72	6	21,222	6
99	7	49	7	99	7	49	7
17,226	8	76	8	19,926	8	76	8
53	9	18,603	9	53	9	21,303	9
80	640	30	690	80	740	30	790
17,307	1	57	1	20,007	1	57	1
34	2	84	2	34	2	84	2
61	3	18,711	3	61	3	21,411	3
88	4	38	4	88	4	38	4
17,415	5	65	5	20,115	5	65	5
42	6	92	6	42	6	92	6
69	7	18,819	7	69	7	21,519	7
96	8	46	8	96	8	46	8
17,523	9	73	9	20,223	9	73	9
50	650	18,900	700	50	750	21,600	800

TABLE 36 — *continued*

21,600–22,950		22,950–24,300		24,300–25,650		25,650–27,000	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
21,627	801	77	851	24,327	901	77	951
54	2	23,004	2	54	2	25,704	2
81	3	31	3	81	3	31	3
21,708	4	58	4	24,408	4	58	4
35	5	85	5	35	5	85	5
62	6	23,112	6	62	6	25,812	6
89	7	39	7	89	7	39	7
21,816	8	66	8	24,516	8	66	8
43	9	93	9	43	9	93	9
70	810	23,220	860	70	910	25,920	960
97	1	47	1	97	1	47	1
21,924	2	74	2	24,624	2	74	2
51	3	23,301	3	51	3	26,001	3
78	4	28	4	78	4	28	4
22,005	5	55	5	24,705	5	55	5
32	6	82	6	32	6	82	6
59	7	23,409	7	59	7	26,109	7
86	8	36	8	86	8	36	8
22,113	9	63	9	24,813	9	63	9
40	820	90	870	40	920	90	970
67	1	23,517	1	67	1	26,217	1
94	2	44	2	94	2	44	2
22,221	3	71	3	24,921	3	71	3
48	4	98	4	48	4	98	4
75	5	23,625	5	75	5	26,325	5
22,302	6	52	6	25,002	6	52	6
29	7	79	7	29	7	79	7
56	8	23,706	8	56	8	26,406	8
83	9	33	9	83	9	33	9
22,410	830	60	880	25,110	930	60	980
37	1	87	1	37	1	87	1
64	2	23,814	2	64	2	26,514	2
91	3	41	3	91	3	41	3
22,518	4	68	4	25,218	4	68	4
45	5	95	5	45	5	95	5
72	6	23,922	6	72	6	26,622	6
99	7	49	7	99	7	49	7
22,626	8	76	8	25,326	8	76	8
53	9	24,003	9	53	9	26,703	9
80	840	30	890	80	940	30	990
22,707	1	57	1	25,407	1	57	1
34	2	84	2	34	2	84	2
61	3	24,111	3	61	3	26,811	3
88	4	38	4	88	4	38	4
22,815	5	65	5	25,515	5	65	5
42	6	92	6	42	6	92	6
69	7	24,219	7	69	7	26,919	7
96	8	46	8	96	8	46	8
22,923	9	73	9	25,623	9	73	9
50	850	24,300	900	50	950	27,000	1000

TABLE 36 — *continued*

27,000–28,350		28,350–29,700		29,700–31,050		31,050–32,400	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
27,027	1001	77	1051	29,727	1101	77	1151
54	2	28,404	2	54	2	31,104	2
81	3	31	3	81	3	31	3
27,108	4	58	4	29,808	4	58	4
35	5	85	5	35	5	85	5
62	6	28,512	6	62	6	31,212	6
89	7	39	7	89	7	39	7
27,216	8	66	8	29,916	8	66	8
43	9	93	9	43	9	93	9
70	1010	28,620	1060	70	1110	31,320	1160
97	1	47	1	97	1	47	1
27,324	2	74	2	30,024	2	74	2
51	3	28,701	3	51	3	31,401	3
78	4	28	4	78	4	28	4
27,405	5	55	5	30,105	5	55	5
32	6	82	6	32	6	82	6
59	7	28,809	7	59	7	31,509	7
86	8	36	8	86	8	36	8
27,513	9	63	9	30,213	9	63	9
40	1020	90	1070	40	1120	90	1170
67	1	28,917	1	67	1	31,617	1
94	2	44	4	94	2	44	2
27,621	3	71	3	30,321	3	71	3
48	4	98	4	48	4	98	4
75	5	29,025	5	75	5	31,725	5
27,702	6	52	6	30,402	6	52	6
29	7	79	7	29	7	79	7
56	8	29,106	8	56	8	31,806	8
83	9	33	9	83	9	33	9
27,810	1030	60	1080	30,510	1130	60	1180
37	1	87	1	37	1	87	1
64	2	29,214	2	64	2	31,914	2
91	3	41	3	91	3	41	3
27,918	4	68	4	30,618	4	68	4
45	5	95	5	45	5	95	5
72	6	29,322	6	72	6	32,022	6
99	7	49	7	99	7	49	7
28,026	8	76	8	30,726	8	76	8
53	9	29,403	9	53	9	32,103	9
80	1040	30	1090	80	1140	30	1190
28,107	1	57	1	30,807	1	57	1
34	2	84	2	34	2	84	2
61	3	29,511	3	61	3	32,211	3
88	4	38	4	88	4	38	4
28.215	5	65	5	30,915	5	65	5
42	6	92	6	42	6	92	6
69	7	29,619	7	69	7	32,319	7
96	8	46	8	96	8	46	8
28,323	9	73	9	31,023	9	73	9
50	1050	29,700	1100	50	1150	32,400	1200

TABLE 36 — *continued*

32,400–33,750		33,750–35,100		35,100–36,450		36,450–37,800	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
32,427	1201	77	1251	35,127	1301	77	1351
54	2	33,804	2	54	2	36,504	2
81	3	31	3	81	3	31	3
32,508	4	58	4	35,208	4	58	4
35	5	85	5	35	5	85	5
62	6	33,912	6	62	6	36,612	6
89	7	39	7	89	7	39	7
32,616	8	66	8	35,316	8	66	8
43	9	93	9	43	9	93	9
70	1210	34,020	1260	70	1310	36,720	1360
97	1	47	1	97	1	47	1
32,724	2	74	2	35,424	2	74	2
51	3	34,101	3	51	3	36,801	3
78	4	28	4	78	4	28	4
32,805	5	55	5	35,505	5	55	5
32	6	82	6	32	6	82	6
59	7	34,209	7	59	7	36,909	7
86	8	36	8	86	8	36	8
32,913	9	63	9	35,613	9	63	9
40	1220	90	1270	40	1320	90	1370
67	1	34,317	1	67	1	37,017	1
94	2	44	2	94	2	44	2
33,021	3	71	3	35,721	3	71	3
48	4	98	4	48	4	98	4
75	5	34,425	5	75	5	37,125	5
33,102	6	52	6	35,802	6	52	6
29	7	79	7	29	7	79	7
56	8	34,506	8	56	8	37,206	8
83	9	33	9	83	9	33	9
33,210	1230	60	1280	35,910	1330	60	1380
37	1	87	1	37	1	87	1
64	2	34,614	2	64	2	37,314	2
91	3	41	3	91	3	41	3
33,318	4	68	4	36,018	4	68	4
45	5	95	5	45	5	95	5
72	6	34,722	6	72	6	37,422	6
99	7	49	7	99	7	49	7
33,426	8	76	8	36,126	8	76	8
53	9	34,803	9	53	9	37,503	9
80	1240	30	1290	80	1340	30	1390
33,507	1	57	1	36,207	1	57	1
34	2	84	2	34	2	84	2
61	3	34,911	3	61	3	37,611	3
88	4	38	4	88	4	38	4
33,615	5	65	5	36,315	5	65	5
42	6	92	6	42	6	92	6
69	7	35,019	7	69	7	37,719	7
96	8	46	8	96	8	46	8
33,723	9	73	9	36,423	9	73	9
50	1250	35,100	1300	50	1350	37,800	1400

TABLE 36 — *continued*

37,800–39,150		39,150–40,500		40,500–41,850		41,850–43,200	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
37,827	1401	77	1451	40,527	1501	77	1551
54	2	39,204	2	54	2	41,904	2
81	3	31	3	81	3	31	3
37,908	4	58	4	40,608	4	58	4
35	5	85	5	35	5	85	5
62	6	39,312	6	62	6	42,012	6
89	7	39	7	89	7	39	7
38,016	8	66	8	40,716	8	66	8
43	9	93	9	43	9	93	9
70	1410	39,420	1460	70	1510	42,120	1560
97	1	47	1	97	1	47	1
38,124	2	74	2	40,824	2	74	2
51	3	39,501	3	51	3	42,201	3
78	4	28	4	78	4	28	4
38,205	5	55	5	40,905	5	55	5
32	6	82	6	32	6	82	6
59	7	39,609	7	59	7	42,309	7
86	8	36	8	86	8	36	8
38,313	9	63	9	41,013	9	63	9
40	1420	90	1470	40	1520	90	1570
67	1	39,717	1	67	1	42,417	1
94	2	44	2	94	2	44	2
38,421	3	71	3	41,121	3	71	3
48	4	98	4	48	4	98	4
75	5	39,825	5	75	5	42,525	5
38,502	6	52	6	41,202	6	52	6
29	7	79	7	29	7	79	7
56	8	39,906	8	56	8	42,606	8
83	9	33	9	83	9	33	9
38,610	1430	60	1480	41,310	1530	60	1580
37	1	87	1	37	1	87	1
64	2	40,014	2	64	2	42,714	2
91	3	41	3	91	3	41	3
38,718	4	68	4	41,418	4	68	4
45	5	95	5	45	5	95	5
72	6	40,122	6	72	6	42,822	6
99	7	49	7	99	7	49	7
38,826	8	76	8	41,526	8	76	8
53	9	40,203	9	53	9	42,903	9
80	1440	30	1490	80	1540	30	1590
38,907	1	57	1	41,607	1	57	1
34	2	84	2	34	2	84	2
61	3	40,311	3	61	3	43,011	3
88	4	38	4	88	4	38	4
39,015	5	65	5	41,715	5	65	5
42	6	92	6	42	6	92	6
69	7	40,419	7	69	7	43,119	7
96	8	46	8	96	8	46	8
39,123	9	73	9	41,823	9	73	9
50	1450	40,500	1500	50	1550	43,200	1600

TABLE 37. NEW YORK STATE DEPARTMENT OF HIGHWAYS.
EARTHWORK COMPUTATION TABLES

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

2	3	4	5	6	7	8	9	10	11	12	13	14	D'uble Areas
0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	1.0
0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	2
0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	4
0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	6
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	8
0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	2.0
0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	2
0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	4
0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	6
0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	8
0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	3.0
0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	2
0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	4
0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	6
0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	8
0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	4.0
0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	2
0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.1	4
0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	6
0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.2	8
0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	5.0
0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	2
0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	4
0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	6
0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	8
0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	6.0
0.2	0.3	0.5	0.6	0.7	0.8	0.9	1.1	1.1	1.3	1.4	1.5	1.6	2
0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.7	4
0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	6
0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.8	8
0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.8	7.0
0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2
0.3	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6	1.8	1.9	4
0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	6
0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.9	2.0	8
0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.1	8.0
0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2
0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2	4
0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.2	6
0.3	0.5	0.7	0.8	1.0	1.1	1.3	1.5	1.6	1.8	2.0	2.1	2.3	8
0.3	0.5	0.7	0.9	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	9.0
0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2
0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	4
0.4	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.8	2.0	2.1	2.3	2.5	6
0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.5	8
0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.4	2.6	10.0
0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	1.9	2.1	2.3	2.5	2.7	5
0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.9	11.0
0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.8	3.0	5
0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.4	2.7	2.9	3.1	12.0
0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.3	2.5	2.8	3.0	3.2	5
0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	2.4	2.6	2.9	3.1	3.4	13.0
0.5	0.7	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.7	3.0	3.3	3.5	5
0.5	0.8	1.0	1.3	1.6	1.8	2.1	2.3	2.6	2.8	3.1	3.4	3.6	14.0

TABLE 37. NEW YORK STATE DEPARTMENT OF HIGHWAYS.
EARTHWORK COMPUTATION TABLES. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

15	16	17	18	19	20	21	22	23	24	25	26	27	D'uble Areas
0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	1.0
0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	2
0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	4
0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	6
0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	8
0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	2.0
0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	2
0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	4
0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	6
0.8	0.8	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	8
0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	3.0
0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6	2
0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7	4
1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.8	6
1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.8	1.9	8
1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	4.0
1.2	1.2	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2
1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	4
1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	6
1.3	1.4	1.5	1.6	1.7	1.8	1.8	2.0	2.0	2.1	2.2	2.3	2.4	8
1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.5	5.0
1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2
1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	4
1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	6
1.6	1.7	1.8	2.0	2.0	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	8
1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.0	6.0
1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	2
1.8	1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.8	3.0	3.1	3.2	4
1.8	2.0	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	6
1.9	2.0	2.1	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	8
1.9	2.1	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	7.0
2.0	2.1	2.3	2.4	2.5	2.7	2.8	2.9	3.1	3.2	3.3	3.5	3.6	2
2.1	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.3	3.4	3.6	3.7	4
2.1	2.3	2.4	2.5	2.7	2.8	3.0	3.1	3.2	3.4	3.5	3.7	3.8	6
2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.8	3.9	8
2.2	2.4	2.5	2.7	2.8	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.0	8.0
2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.8	4.0	4.1	2
2.3	2.5	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.7	3.9	4.1	4.2	4
2.4	2.5	2.7	2.9	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.1	4.3	6
2.4	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.8	3.9	4.1	4.2	4.4	8
2.5	2.7	2.8	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.2	4.3	4.5	9.0
2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	2
2.6	2.8	3.0	3.1	3.3	3.5	3.7	3.8	4.0	4.2	4.4	4.5	4.7	4
2.7	2.8	3.0	3.2	3.4	3.6	3.7	3.9	4.1	4.3	4.5	4.6	4.8	6
2.7	2.9	3.1	3.3	3.4	3.6	3.8	4.0	4.2	4.4	4.5	4.7	4.9	8
2.8	3.0	3.1	3.3	3.5	3.7	3.9	4.1	4.2	4.4	4.6	4.8	5.0	100
2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.6	4.9	5.0	5.3	5
3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	11.0
3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5
3.3	3.6	3.8	4.0	4.2	4.5	4.7	4.9	5.1	5.3	5.5	5.8	6.0	12.0
3.5	3.7	3.9	4.2	4.4	4.6	4.9	5.1	5.3	5.5	5.8	6.0	6.2	5
3.6	3.8	4.1	4.3	4.6	4.8	5.0	5.3	5.5	5.8	6.0	6.3	6.5	13.0
3.7	4.0	4.2	4.5	4.8	5.0	5.2	5.5	5.8	6.0	6.3	6.5	6.7	5
3.9	4.1	4.4	4.7	4.9	5.2	5.4	5.7	6.0	6.2	6.5	6.7	7.0	14.0

TABLE 37.—*continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

28	29	30	31	32	33	34	35	36	37	38	39	40	D'uble Areas
0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	1.0
0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	2
0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	4
0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	6
0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	8
1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	2.0
1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	2
1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	4
1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	6
1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	8
1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	3.0
1.7	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2
1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	4
1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	6
2.0	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	8
2.1	2.2	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	3.0	4.0
2.2	2.3	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	2
2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3	4
2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	6
2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	8
2.6	2.7	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.4	3.5	3.6	3.7	5.0
2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	2
2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4
2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.1	4.2	6
3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	8
3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.5	6.0
3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.6	2
3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.7	4
3.4	3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	6
3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.0	8
3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	7.0
3.7	3.9	4.0	4.1	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.3	2
3.8	4.0	4.1	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.4	5.5	4
3.9	4.1	4.2	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.4	5.5	5.6	6
4.0	4.2	4.3	4.5	4.6	4.8	4.9	5.1	5.2	5.4	5.5	5.6	5.8	8
4.2	4.3	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.5	5.6	5.8	5.9	8.0
4.3	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.5	5.6	5.8	5.9	6.1	2
4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.6	5.8	5.9	6.1	6.2	4
4.5	4.6	4.8	4.9	5.1	5.3	5.4	5.6	5.7	5.9	6.1	6.2	6.4	6
4.6	4.7	4.9	5.1	5.2	5.4	5.5	5.7	5.9	6.0	6.2	6.4	6.5	8
4.7	4.8	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.2	6.3	6.5	6.7	9.0
4.8	4.9	5.1	5.3	5.5	5.6	5.8	6.0	6.1	6.3	6.5	6.7	6.8	2
4.9	5.1	5.2	5.4	5.6	5.8	5.9	6.1	6.3	6.5	6.6	6.8	7.0	4
5.0	5.2	5.3	5.5	5.7	5.9	6.1	6.2	6.4	6.6	6.8	6.9	7.1	6
5.1	5.3	5.5	5.6	5.8	6.0	6.2	6.3	6.5	6.7	6.9	7.1	7.3	8
5.2	5.4	5.6	5.8	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.2	7.4	10.0
5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	5
5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.8	7.9	8.2	11.0
6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.5	7.7	7.9	8.1	8.3	8.5	5
6.2	6.4	6.7	7.0	7.1	7.3	7.6	7.8	8.0	8.2	8.5	8.7	8.9	12.0
6.5	6.7	7.0	7.2	7.4	7.7	7.9	8.1	8.3	8.6	8.8	9.0	9.3	5
6.7	7.0	7.2	7.5	7.7	8.0	8.2	8.4	8.7	8.9	9.2	9.4	9.6	13.0
7.0	7.3	7.5	7.8	8.0	8.3	8.5	8.8	9.0	9.3	9.5	9.8	10.0	5
7.2	7.5	7.8	8.0	8.3	8.6	8.8	9.1	9.3	9.6	9.8	10.1	10.4	14.0

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

41	42	43	44	45	46	47	48	49	50	75	100		D'uble Areas
0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.4	1.9		1.0
0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.6	2.2		2
1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.9	2.6		4
1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	2.2	3.0		6
1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.7	2.5	3.3		8
1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8	2.8	3.7		2.0
1.7	1.7	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0	3.1	4.1		2
1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2	2.2	3.3	4.4		4
2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	3.6	4.8		6
2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.6	3.9	5.2		8
2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7	2.8	4.2	5.6		3.0
2.4	2.5	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	4.4	5.9		2
2.6	2.6	2.7	2.8	2.8	2.9	3.0	3.0	3.1	3.2	4.7	6.3		4
2.7	2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.3	3.3	5.0	6.7		6
2.9	3.0	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.5	5.3	7.0		8
3.0	3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.6	3.7	5.6	7.4		4.0
3.2	3.3	3.4	3.4	3.5	3.6	3.7	3.7	3.8	3.9	5.9	7.9		2
3.3	3.4	3.5	3.6	3.7	3.8	3.8	3.9	4.0	4.1	6.1	8.2		4
3.5	3.6	3.7	3.8	3.8	3.9	4.0	4.1	4.2	4.3	6.4	8.5		6
3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	6.7	8.9		8
3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.5	4.6	7.0	9.3		5.0
4.0	4.1	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	7.2	9.7		2
4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	7.5	10.0		4
4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	7.8	0.4		6
4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.4	8.1	0.8		8
4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.6	8.3	1.1		6.0
4.7	4.8	4.9	5.0	5.2	5.3	5.4	5.5	5.6	5.7	8.6	1.5		2
4.9	5.0	5.1	5.2	5.3	5.5	5.6	5.7	5.8	5.9	8.9	1.8		4
5.0	5.1	5.2	5.4	5.5	5.6	5.7	5.9	6.0	6.1	9.2	2.2		6
5.2	5.3	5.4	5.5	5.7	5.8	5.9	6.0	6.2	6.3	9.5	2.6		8
5.3	5.4	5.6	5.7	5.8	5.9	6.1	6.2	6.3	6.5	9.7	3.0		7.0
5.5	5.6	5.7	5.8	6.0	6.1	6.3	6.4	6.5	6.7	10.0	3.4		2
5.6	5.7	5.9	6.0	6.2	6.3	6.4	6.6	6.7	6.8	0.3	3.7		4
5.8	5.9	6.0	6.2	6.3	6.5	6.6	6.7	6.9	7.0	0.6	4.1		6
5.9	6.1	6.2	6.3	6.5	6.6	6.8	6.9	7.1	7.2	0.8	4.4		8
6.1	6.2	6.4	6.5	6.7	6.8	7.0	7.1	7.2	7.4	11.1	4.8		8.0
6.2	6.3	6.5	6.6	6.8	7.0	7.1	7.3	7.4	7.6	1.4	5.2		2
6.4	6.5	6.7	6.8	7.0	7.2	7.3	7.5	7.6	7.8	1.7	5.6		4
6.5	6.7	6.8	7.0	7.2	7.3	7.5	7.7	7.8	8.0	2.0	6.0		6
6.7	6.9	7.0	7.2	7.3	7.5	7.7	7.8	8.0	8.2	2.2	6.3		8
6.8	7.0	7.2	7.3	7.5	7.7	7.8	8.0	8.2	8.3	12.5	6.6		9.0
7.0	7.2	7.3	7.5	7.7	7.8	8.0	8.2	8.3	8.5	2.8	7.0		2
7.1	7.3	7.5	7.7	7.8	8.0	8.2	8.4	8.5	8.7	3.1	7.4		4
7.3	7.5	7.6	7.8	8.0	8.2	8.3	8.5	8.7	8.9	3.3	7.8		6
7.4	7.6	7.8	8.0	8.2	8.4	8.5	8.7	8.9	9.1	3.6	8.2		8
7.6	7.8	8.0	8.1	8.3	8.5	8.7	8.9	9.1	9.3	13.9	8.5		10.0
8.0	8.2	8.4	8.6	8.8	8.9	9.1	9.3	9.5	9.7	4.6	9.5		5
8.3	8.5	8.7	8.9	9.2	9.4	9.6	9.8	10.0	10.2	5.3	20.3		11.0
8.7	8.9	9.1	9.4	9.6	9.8	10.0	10.2	0.4	0.7	6.0	1.3		5
9.1	9.3	9.5	9.8	10.0	10.2	0.4	0.7	0.9	1.1	6.7	2.2		12.0
9.5	9.7	10.0	10.2	10.4	10.6	10.8	11.1	11.4	11.6	17.4	23.2		5
9.9	10.1	0.4	0.6	0.8	1.1	1.3	1.6	1.8	2.1	8.0	4.1		13.0
10.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	8.8	5.0		5
0.6	0.9	1.2	1.4	1.7	1.9	2.2	2.4	2.7	3.0	9.4	6.0		14.0

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

2	3	4	5	6	7	8	9	10	11	12	13	14	D'uble Areas
0.5	0.8	1.1	1.3	1.6	1.9	2.1	2.4	2.7	3.0	3.2	3.5	3.8	14.5
0.6	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.1	3.3	3.6	3.9	15.0
0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	2.9	3.2	3.4	3.7	4.0	5
0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.8	4.1	16.0
0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.1	3.4	3.7	4.0	4.3	5
0.6	0.9	1.3	1.6	1.9	2.2	2.5	2.8	3.1	3.5	3.8	4.1	4.4	17.0
0.6	1.0	1.3	1.6	2.0	2.3	2.6	2.9	3.2	3.6	3.9	4.2	4.5	5
0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	18.0
0.7	1.0	1.4	1.7	2.1	2.4	2.7	3.1	3.4	3.8	4.1	4.4	4.8	5
0.7	1.1	1.4	1.8	2.1	2.5	2.8	3.2	3.5	3.9	4.2	4.6	4.9	19.0
0.7	1.1	1.4	1.8	2.2	2.5	2.9	3.2	3.6	4.0	4.3	4.7	5.0	5
0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.3	3.7	4.1	4.4	4.8	5.2	20.0
0.8	1.2	1.6	2.0	2.3	2.7	3.1	3.5	3.9	4.3	4.7	5.1	5.4	1
0.8	1.2	1.6	2.0	2.4	2.8	3.3	3.7	4.1	4.5	4.9	5.3	5.7	2
0.9	1.3	1.7	2.1	2.6	3.0	3.4	3.8	4.3	4.7	5.1	5.5	6.0	3
0.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	4.9	5.3	5.8	6.2	4
0.9	1.4	1.9	2.3	2.8	3.2	3.7	4.2	4.6	5.1	5.6	6.0	6.5	25.0
1.0	1.4	1.9	2.4	2.9	3.4	3.9	4.3	4.8	5.3	5.8	6.3	6.7	6
1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7
1.0	1.6	2.1	2.6	3.1	3.6	4.2	4.7	5.2	5.7	6.2	6.7	7.3	8
1.1	1.6	2.1	2.7	3.2	3.8	4.3	4.8	5.4	5.9	6.4	7.0	7.5	9
1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.5	6.1	6.7	7.2	7.8	30.0
1.2	1.7	2.3	2.9	3.4	4.0	4.6	5.2	5.7	6.3	6.9	7.5	8.0	1
1.2	1.8	2.4	3.0	3.6	4.2	4.7	5.3	6.0	6.5	7.1	7.7	8.3	2
1.2	1.8	2.4	3.0	3.7	4.3	4.9	5.5	6.1	6.7	7.3	8.0	8.6	3
1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.7	6.3	6.9	7.5	8.2	8.8	4
1.3	1.9	2.6	3.2	3.9	4.5	5.2	5.8	6.5	7.1	7.8	8.4	9.1	35.0
1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	6
1.4	2.1	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.5	8.2	8.9	9.6	7
1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0	7.7	8.4	9.2	9.8	8
1.4	2.2	2.9	3.6	4.3	5.0	5.8	6.5	7.2	7.9	8.7	9.4	10.1	9
1.5	2.2	3.0	3.7	4.4	5.2	5.9	6.7	7.4	8.1	8.9	9.7	0.4	40.0
1.5	2.3	3.0	3.8	4.5	5.3	6.1	6.8	7.6	8.3	9.1	9.9	0.6	1
1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.8	8.5	9.3	10.1	0.9	2
1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	8.8	9.6	10.4	1.2	3
1.6	2.4	3.3	4.1	4.9	5.7	6.5	7.3	8.2	9.0	9.8	10.6	11.4	4
1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0	0.9	1.7	45.0
1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5	9.4	0.2	1.1	1.9	6
1.7	2.6	3.5	4.3	5.2	6.1	7.0	7.8	8.7	9.6	0.5	1.3	2.2	7
1.8	2.7	3.6	4.4	5.3	6.2	7.1	8.0	8.9	9.8	0.7	1.6	2.4	8
1.8	2.7	3.6	4.5	5.4	6.4	7.3	8.2	9.1	10.0	10.9	11.8	12.7	9
1.8	2.8	3.7	4.6	5.6	6.5	7.4	8.3	9.3	0.2	1.1	2.1	2.9	50.0
1.9	2.9	3.9	4.8	5.8	6.7	7.7	8.7	9.6	0.6	1.6	2.5	3.5	2
2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	1.0	2.0	3.0	4.0	4
2.1	3.1	4.1	5.2	6.2	7.3	8.3	9.3	0.4	1.4	2.5	3.5	4.5	6
2.2	3.2	4.3	5.4	6.4	7.5	8.6	9.7	10.7	11.8	12.9	13.9	15.0	8
2.2	3.3	4.4	5.5	6.7	7.8	8.9	10.0	1.1	2.2	3.3	4.4	5.5	60.0
2.3	3.4	4.6	5.7	6.9	8.0	9.2	0.3	1.5	2.6	3.8	4.9	6.1	2
2.4	3.6	4.7	5.9	7.1	8.3	9.5	0.7	1.9	3.0	4.2	5.4	6.6	4
2.4	3.7	4.9	6.1	7.3	8.6	9.8	1.0	2.2	3.4	4.7	5.9	7.1	6
2.5	3.8	5.0	6.3	7.5	8.8	10.1	11.4	12.6	13.8	15.1	16.4	17.6	8
2.6	3.9	5.2	6.5	7.8	9.1	10.4	1.7	3.0	4.3	5.5	6.8	8.2	70.0
2.7	4.0	5.3	6.7	8.0	9.3	10.7	2.0	3.4	4.7	6.0	7.3	8.6	2
2.7	4.1	5.5	6.9	8.2	9.6	10.9	2.3	3.7	5.1	6.5	7.8	9.2	4

TABLE 37.—*continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

15	16	17	18	19	20	21	22	23	24	25	26	27	D'uble Areas
4.0	4.3	4.6	4.8	5.1	5.4	5.6	5.9	6.2	6.5	6.7	6.9	7.3	14.5
4.2	4.4	4.7	5.0	5.3	5.6	5.8	6.1	6.4	6.7	6.9	7.2	7.5	15.0
4.3	4.6	4.9	5.2	5.5	5.7	6.0	6.3	6.6	6.9	7.2	7.5	7.8	5
4.5	4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.7	8.0	16.0
4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.7	8.0	8.3	5
4.7	5.1	5.3	5.7	6.0	6.3	6.6	6.9	7.2	7.6	7.9	8.2	8.5	17.0
4.9	5.2	5.5	5.8	6.2	6.5	6.8	7.1	7.5	7.8	8.1	8.4	8.8	5
5.0	5.3	5.7	6.0	6.3	6.7	7.0	7.4	7.7	8.0	8.4	8.7	9.0	18.0
5.1	5.5	5.8	6.2	6.5	6.8	7.2	7.5	7.9	8.2	8.6	8.9	9.3	5
5.3	5.6	6.0	6.3	6.7	7.0	7.4	7.7	8.1	8.5	8.8	9.2	9.5	19.0
5.4	5.8	6.1	6.5	6.8	7.2	7.6	7.9	8.3	8.7	9.0	9.4	9.8	5
5.6	5.9	6.3	6.7	7.0	7.4	7.8	8.2	8.5	8.9	9.3	9.7	10.0	20.0
5.8	6.2	6.6	7.0	7.4	7.8	8.2	8.6	9.0	9.3	9.7	10.1	0.5	1
6.1	6.5	6.9	7.3	7.7	8.1	8.6	9.0	9.4	9.8	10.2	0.6	1.0	2
6.4	6.8	7.2	7.7	8.1	8.5	8.9	9.4	9.8	10.2	0.6	1.1	1.5	3
6.7	7.1	7.5	8.0	8.4	8.9	9.3	9.8	10.2	10.7	11.1	11.6	12.0	4
7.0	7.4	7.9	8.3	8.8	9.3	9.7	10.2	0.7	1.1	1.6	2.1	2.5	25.0
7.2	7.7	8.2	8.7	9.1	9.6	10.1	0.6	1.1	1.6	2.0	2.5	3.0	6
7.5	8.0	8.5	9.0	9.5	10.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	7
7.8	8.3	8.8	9.3	9.8	0.4	0.9	1.4	1.9	2.4	3.0	3.5	4.0	8
8.1	8.6	9.1	9.7	10.2	10.7	11.3	11.8	12.4	12.9	13.4	13.9	14.5	9
8.3	8.9	9.5	10.0	0.5	1.1	1.7	2.2	2.8	3.3	3.9	4.5	5.0	30.0
8.6	9.2	9.8	0.3	0.9	1.5	2.1	2.6	3.2	3.8	4.3	4.9	5.5	1
8.9	9.5	10.1	0.7	1.3	1.9	2.5	3.0	3.6	4.2	4.8	5.4	6.0	2
9.2	9.8	0.4	1.0	1.6	2.2	2.9	3.5	4.1	4.7	5.3	5.9	6.5	3
9.5	10.1	10.7	11.3	12.0	12.6	13.3	13.9	14.5	15.1	15.7	16.4	17.0	4
9.7	0.3	1.0	1.7	2.3	2.9	3.6	4.3	4.9	5.5	6.2	6.9	7.5	35.0
10.0	0.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	6
0.3	0.9	1.7	2.3	3.0	3.7	4.4	5.1	5.8	6.5	7.1	7.8	8.5	7
0.6	1.3	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.3	9.0	8
10.8	11.6	12.3	13.0	13.7	14.5	15.2	15.9	16.6	17.3	18.1	18.8	19.5	9
1.2	1.8	2.6	3.3	4.1	4.8	5.6	6.3	7.1	7.8	8.5	9.3	20.0	40.0
1.4	2.1	2.9	3.7	4.4	5.2	6.0	6.7	7.5	8.1	9.0	9.7	0.5	1
1.7	2.4	3.2	4.0	4.8	5.5	6.3	7.1	7.9	8.7	9.4	20.2	1.0	2
2.0	2.7	3.5	4.3	5.1	5.9	6.7	7.5	8.3	9.1	9.9	0.7	1.5	3
12.2	13.1	13.9	14.7	15.5	16.3	17.1	17.9	18.7	19.6	20.4	21.2	22.0	4
2.5	3.3	4.2	5.0	5.9	6.7	7.5	8.3	9.2	20.0	0.8	1.7	2.5	45.0
2.9	3.6	4.5	5.3	6.2	7.1	7.9	8.7	9.6	0.4	1.3	2.2	3.0	6
3.1	3.9	4.9	5.7	6.5	7.4	8.3	9.1	20.1	0.9	1.7	2.6	3.5	7
3.4	4.2	5.1	6.0	6.9	7.8	8.7	9.6	0.4	1.3	2.2	3.2	4.0	8
13.6	14.5	15.4	16.3	17.2	18.1	19.1	20.0	20.8	21.8	22.7	23.6	24.5	9
3.9	4.8	5.7	6.7	7.6	8.5	9.5	0.4	1.3	2.3	3.2	4.1	5.0	50.0
4.4	5.4	6.4	7.4	8.3	9.3	20.2	1.2	2.2	3.2	4.1	5.1	6.0	2
5.0	6.0	7.0	8.0	9.0	20.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	4
5.6	6.6	7.6	8.7	9.7	0.8	1.8	2.8	3.8	4.8	5.9	6.9	8.0	6
16.1	17.2	18.3	19.4	20.4	21.5	22.5	23.6	24.7	25.7	26.8	27.8	29.0	8
6.7	7.8	8.9	20.0	1.1	2.2	3.4	4.4	5.6	6.6	7.7	8.8	30.0	60.0
7.2	8.4	9.5	0.7	1.8	2.9	4.2	5.2	6.4	7.6	8.7	9.8	1.0	2
7.8	8.9	20.2	1.4	2.5	3.7	4.9	6.0	7.3	8.4	9.6	30.8	2.0	4
8.4	9.5	0.8	2.0	3.2	4.4	5.7	6.8	8.1	9.3	30.6	1.7	3.0	6
18.9	20.1	21.4	22.6	23.9	25.2	26.4	27.7	29.0	30.2	31.5	32.7	34.0	8
9.4	0.7	2.0	3.4	4.6	5.9	7.2	8.5	9.8	1.1	2.4	3.7	5.0	70.0
20.0	1.4	2.6	4.0	5.4	6.7	8.0	9.4	30.7	2.0	3.4	4.6	6.0	2
06	1.8	3.3	4.7	6.0	7.4	8.8	30.2	1.5	2.9	4.3	5.7	7.0	4

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

28	29	30	31	32	33	34	35	36	37	38	39	40	D'uble Areas
7.5	7.8	8.1	8.3	8.6	8.8	9.1	9.4	9.7	9.9	10.2	10.5	10.7	14.5
7.8	8.0	8.3	8.6	8.9	9.2	9.5	9.7	10.0	10.3	0.6	0.9	1.1	15.0
8.0	8.3	8.6	8.9	9.2	9.5	9.8	10.0	0.3	0.6	0.9	1.2	1.5	5
8.3	8.6	8.9	9.2	9.5	9.8	10.1	0.3	0.7	1.0	1.3	1.6	1.9	16.0
8.5	8.9	9.2	9.5	9.8	10.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	5
8.8	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.7	11.9	12.3	12.6	17.0
9.1	9.4	9.7	10.1	0.4	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	5
9.3	9.7	10.0	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	18.0
9.6	9.9	0.3	0.6	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	5
9.8	10.2	0.5	0.9	1.3	1.6	1.9	2.3	2.7	3.0	3.3	3.7	4.1	19.0
10.1	10.5	10.8	11.2	11.6	11.9	12.3	12.6	13.0	13.3	13.7	14.1	14.4	5
0.4	0.7	1.1	1.5	1.9	2.2	2.6	2.9	3.3	3.7	4.1	4.5	4.8	20.0
0.9	1.3	1.7	2.1	2.5	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.5	1
1.4	1.8	2.2	2.6	3.1	3.4	3.9	4.2	4.7	5.1	5.5	5.9	6.3	2
1.9	2.4	2.8	3.2	3.6	4.1	4.5	4.9	5.3	5.7	6.2	6.6	7.1	3
12.5	12.9	13.3	13.8	14.2	14.7	15.1	15.5	16.0	16.4	16.9	17.3	17.8	4
2.9	3.4	3.9	4.4	4.8	5.3	5.7	6.2	6.7	7.1	7.6	8.1	8.5	25.0
3.5	3.9	4.4	4.9	5.4	5.9	6.4	6.8	7.3	7.9	8.3	8.8	9.3	6
4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	20.0	7
4.5	5.1	5.5	6.1	6.6	7.1	7.6	8.1	8.7	9.2	9.7	20.2	0.7	8
15.1	15.5	16.1	16.6	17.2	17.7	18.3	18.8	19.3	19.9	20.4	20.9	21.5	9
5.5	6.1	6.7	7.2	7.8	8.3	8.9	9.4	9.9	20.6	1.2	1.7	2.2	30.0
6.1	6.6	7.2	7.8	8.4	8.9	9.5	20.1	20.7	1.2	1.8	2.4	2.9	1
6.6	7.2	7.7	8.3	8.9	9.6	20.2	0.6	1.3	1.9	2.5	3.2	3.7	2
7.1	7.7	8.3	8.9	9.5	20.2	0.7	1.4	1.9	2.6	3.2	3.8	4.4	3
17.6	18.3	18.9	19.5	20.2	20.8	21.4	22.0	22.7	23.3	23.8	24.6	25.2	4
8.1	8.7	9.5	20.1	0.7	1.3	2.1	2.7	3.3	3.9	4.7	5.3	5.9	35.0
8.7	9.3	20.0	0.7	1.3	1.9	2.7	3.3	3.9	4.6	5.3	6.0	6.7	6
9.2	9.9	0.6	1.2	1.9	2.6	3.2	3.9	4.6	5.3	6.0	6.7	7.4	7
9.7	20.4	1.1	1.8	2.5	3.2	3.9	4.6	5.3	6.0	6.7	7.4	8.1	8
20.2	20.9	21.7	22.3	23.2	23.8	24.6	25.3	25.9	26.7	27.4	28.2	28.9	9
0.7	1.4	2.2	2.9	3.7	4.4	5.2	5.9	6.6	7.4	8.1	8.8	9.6	40.0
1.3	1.9	2.8	3.6	4.3	5.1	5.7	6.5	7.3	8.1	8.8	9.6	30.4	1
1.8	2.6	3.3	4.2	4.8	5.6	6.4	7.2	7.9	8.7	9.6	30.3	1.0	2
2.3	3.1	3.8	4.7	5.4	6.2	7.1	7.8	8.6	9.4	30.2	1.1	1.8	3
22.8	23.6	24.4	25.2	26.1	26.8	27.7	28.4	29.3	30.2	30.9	31.7	32.6	4
3.3	4.2	5.0	5.8	6.6	7.5	8.4	9.2	9.9	0.8	1.7	2.5	3.4	45.0
3.8	4.7	5.6	6.4	7.2	8.1	8.9	9.8	30.6	1.5	2.4	3.2	4.1	6
4.3	5.2	6.1	6.9	7.8	8.7	9.6	30.4	1.3	2.2	3.0	3.9	4.8	7
4.8	5.7	6.7	7.6	8.4	9.3	30.2	1.1	2.0	2.8	3.7	4.7	5.5	8
25.4	26.3	27.2	28.2	29.0	29.9	30.8	31.7	32.6	33.6	34.5	35.4	36.3	9
5.9	6.8	7.8	8.7	9.6	30.5	1.4	2.4	3.4	4.2	5.2	6.2	7.1	50.0
6.9	7.8	8.8	9.8	30.8	1.7	2.7	3.7	4.6	5.6	6.6	7.5	8.5	2
7.9	8.9	9.9	30.9	2.0	3.0	4.0	5.0	5.9	6.9	8.0	9.0	40.0	4
9.0	30.1	31.1	2.1	3.2	4.2	5.2	6.2	7.3	8.3	9.4	40.4	1.5	6
30.1	31.1	32.2	33.2	34.4	35.4	36.5	37.5	38.6	39.6	40.8	41.8	42.9	8
1.1	2.2	3.3	4.4	5.6	6.6	7.7	8.9	40.0	41.1	2.2	3.4	4.4	60.0
2.1	3.2	4.4	5.6	6.7	7.8	9.0	40.1	1.3	2.4	3.6	4.8	5.9	2
3.2	4.4	5.5	6.6	7.8	9.1	40.2	1.4	2.6	3.8	5.0	6.2	7.4	4
4.2	5.4	6.6	7.8	9.1	40.2	1.5	2.7	3.9	5.2	6.4	7.6	8.8	6
35.2	36.4	37.7	39.0	40.2	41.5	42.8	44.0	45.2	46.5	47.8	49.0	50.4	8
6.3	7.6	8.8	40.1	1.4	2.8	4.0	5.4	6.6	8.0	9.2	50.5	1.8	70.0
7.3	8.7	9.9	1.3	2.6	4.0	5.3	6.6	8.0	9.2	50.6	2.0	3.3	2
8.4	9.7	41.1	2.5	3.8	5.2	6.6	7.9	9.4	50.7	2.1	3.4	4.8	4

TABLE 37.—*continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

41	42	43	44	45	46	47	48	49	50	75	100	—	D'uble Areas
11.0	11.3	11.5	11.8	12.1	12.3	12.6	12.9	13.1	13.4	20.2	26.8	—	14.5
1.4	1.7	1.9	2.2	2.5	2.8	3.0	3.3	3.6	3.9	0.8	7.8	—	15.0
1.8	2.1	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.4	1.5	8.7	—	5
2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	2.2	9.6	—	16.0
2.5	2.8	3.1	3.4	3.7	4.1	4.3	4.7	4.9	5.3	2.8	30.5	—	5
12.9	13.2	13.5	13.8	14.2	14.5	14.8	15.1	15.4	15.7	23.6	31.4	—	17.0
3.3	3.6	3.9	4.3	4.6	4.9	5.2	5.5	5.9	6.2	4.3	2.4	—	5
3.7	4.0	4.3	4.7	5.0	5.3	5.7	6.0	6.3	6.7	4.9	3.3	—	18.0
4.1	4.4	4.7	5.1	5.4	5.7	6.1	6.4	6.7	7.1	5.7	4.2	—	5
4.4	4.7	5.1	5.5	5.8	6.1	6.5	6.9	7.2	7.6	6.4	5.2	—	19.0
14.8	15.1	15.5	15.9	16.3	16.6	16.9	17.3	17.7	18.1	27.1	36.1	—	5
5.2	5.5	5.9	6.3	6.7	7.1	7.4	7.7	8.1	8.5	7.8	7.0	—	20.0
5.9	6.3	6.7	7.1	7.5	7.9	8.3	8.7	9.0	9.5	9.2	8.8	—	1
6.7	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.9	20.4	30.6	40.7	—	2
7.5	7.9	8.3	8.7	9.1	9.6	20.0	20.4	20.8	1.3	1.9	2.6	—	3
18.2	18.6	19.1	19.5	20.0	20.4	20.8	21.3	21.8	22.2	33.2	44.4	—	4
9.0	9.5	9.9	20.3	0.8	1.3	1.7	2.2	2.7	3.2	4.7	6.2	—	25.0
9.7	20.2	20.7	1.2	1.7	2.2	2.6	3.1	3.6	4.1	6.1	8.2	—	6
20.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	50.0	—	7
1.3	1.8	2.3	2.8	3.3	3.8	4.4	4.8	5.4	5.9	8.8	1.8	—	8
22.0	22.6	23.1	23.7	24.2	24.7	25.2	25.8	26.3	26.8	40.3	53.7	—	9
2.8	3.3	3.8	4.4	5.0	5.5	6.1	6.7	7.2	7.8	1.6	5.5	—	30.0
3.5	4.1	4.7	5.2	5.8	6.4	6.9	7.6	8.1	8.7	3.2	7.3	—	1
4.3	4.8	5.4	6.1	6.6	7.2	7.8	8.4	9.1	9.6	4.4	9.2	—	2
5.0	5.7	6.3	6.8	7.5	8.1	8.7	9.3	9.9	30.6	5.8	61.0	—	3
25.7	26.4	27.0	27.7	28.3	28.9	29.6	30.2	30.8	31.4	47.2	62.9	—	4
6.6	7.2	7.8	8.5	9.2	9.8	30.4	1.1	1.7	2.4	8.6	4.8	—	35.0
7.3	8.0	8.6	9.3	30.0	30.6	1.3	2.0	2.6	3.3	9.9	6.7	—	6
8.1	8.8	9.4	30.1	0.8	1.5	2.2	2.8	3.6	4.3	51.4	8.5	—	7
8.8	9.6	30.2	1.0	1.6	2.4	3.1	3.7	4.5	5.2	2.8	70.4	—	8
29.6	30.4	31.0	31.7	32.5	33.2	33.8	34.6	35.4	36.1	54.1	72.1	—	9
30.4	1.2	1.8	2.6	3.3	4.0	4.8	5.6	6.3	7.0	5.5	4.0	—	40.0
1.2	1.8	2.6	3.4	4.2	4.8	5.6	6.4	7.2	8.0	6.9	5.8	—	1
1.8	2.7	3.4	4.2	5.0	5.8	6.6	7.3	8.2	8.9	8.3	7.8	—	2
2.6	3.4	4.2	5.0	5.8	6.6	7.4	8.2	9.0	9.8	9.6	9.6	—	3
33.4	34.2	35.0	35.8	36.7	37.4	38.3	39.2	39.9	40.8	61.1	81.5	—	4
4.2	4.9	5.8	6.7	7.4	8.3	9.2	9.9	40.7	1.6	2.4	3.4	—	45.0
4.8	5.7	6.6	7.4	8.3	9.1	40.0	40.9	1.7	2.6	3.8	5.1	—	6
5.7	6.6	7.4	8.3	9.2	40.0	0.9	1.8	2.7	3.5	5.3	7.0	—	7
6.4	7.3	8.2	9.2	40.0	0.8	1.7	2.6	3.5	4.4	6.7	8.9	—	8
37.2	38.1	39.0	39.9	40.8	41.7	42.6	43.5	44.4	45.3	68.1	90.6	—	9
7.9	8.8	9.8	40.7	1.6	2.6	3.5	4.4	5.3	6.4	9.3	2.6	—	50.0
9.5	40.4	41.3	2.3	3.3	4.2	5.2	6.2	7.2	8.2	72.2	6.3	—	2
41.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	50.0	5.0	100.0	—	4
2.5	3.5	4.6	5.6	6.6	7.7	8.7	9.8	50.8	1.8	7.8	03.6	—	6
44.1	45.2	46.2	47.3	48.4	49.4	50.5	51.5	52.6	53.7	80.5	107.3	—	8
5.6	6.7	7.8	8.9	50.0	51.1	2.2	3.3	4.4	5.5	3.4	11.0	—	60.0
7.1	8.2	9.4	50.5	1.6	2.8	4.0	5.1	6.2	7.4	6.1	14.8	—	2
8.6	9.7	50.9	2.1	3.3	4.5	5.7	6.9	8.1	9.3	8.9	18.6	—	4
50.2	51.3	2.5	3.7	5.0	6.1	7.4	8.6	9.9	61.1	91.7	22.1	—	6
51.6	52.8	54.1	55.4	56.7	58.0	59.2	60.4	61.7	63.0	94.5	125.9	—	8
3.1	4.4	5.7	7.0	8.3	9.6	60.9	2.2	3.5	4.8	7.2	29.5	—	70.0
4.7	6.0	7.3	8.6	60.0	61.3	2.6	4.0	5.4	6.6	100.0	33.2	—	2
6.2	7.6	8.9	60.3	1.7	3.1	4.4	5.8	7.2	8.6	02.9	37.1	—	4

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

2	3	4	5	6	7	8	9	10	11	12	13	14	D'uble Areas
2.8	4.2	5.6	7.0	8.5	9.9	11.3	12.7	14.1	15.5	16.9	18.3	19.7	76.0
2.9	4.3	5.8	7.2	8.7	10.1	1.6	3.0	4.5	5.9	7.4	8.8	20.2	8
3.0	4.4	5.9	7.4	8.9	0.4	1.9	3.3	4.9	6.3	7.8	9.3	0.8	80.0
3.0	4.6	6.1	7.6	9.1	0.7	2.2	3.7	5.2	6.7	8.2	9.8	1.3	2
3.1	4.7	6.2	7.8	9.3	0.9	2.5	4.0	5.6	7.1	8.7	20.2	1.7	4
3.2	4.8	6.4	8.0	9.6	11.2	12.7	14.3	15.9	17.5	19.1	20.7	22.3	6
3.3	4.9	6.5	8.1	9.8	1.4	3.1	4.7	6.3	7.9	9.5	1.2	2.8	8
3.3	5.0	6.7	8.3	10.0	1.7	3.3	5.0	6.7	8.3	20.0	1.7	3.4	90.0
3.4	5.1	6.8	8.5	0.2	1.9	3.6	5.4	7.1	8.7	0.4	2.1	3.8	2
3.5	5.2	7.0	8.7	0.5	2.2	3.9	5.7	7.4	9.2	0.8	2.6	4.4	4
3.5	5.3	7.1	8.9	10.7	12.5	14.2	16.0	17.8	19.5	21.3	23.1	24.9	6
3.6	5.4	7.3	9.1	0.9	2.7	4.5	6.4	8.2	9.9	1.8	3.6	5.4	8
3.7	5.6	7.4	9.3	1.1	3.0	4.8	6.7	8.5	20.4	2.2	4.1	6.0	100.0
3.9	5.8	7.8	9.7	1.7	3.6	5.5	7.5	9.5	1.4	3.3	5.3	7.2	05
4.1	6.1	8.1	10.2	2.2	4.3	6.3	8.4	20.4	2.4	4.4	6.5	8.6	10
4.3	6.4	8.5	10.7	12.8	14.9	17.0	19.1	21.3	23.4	25.5	27.7	29.8	15
4.4	6.7	8.9	1.1	3.3	5.5	7.8	20.0	2.3	4.4	6.6	8.8	31.2	20
4.6	6.9	9.2	1.6	3.9	6.2	8.5	0.8	3.2	5.4	7.7	30.2	2.4	125.0
4.8	7.2	9.6	2.1	4.5	6.9	9.3	1.7	4.1	6.5	8.8	1.4	3.7	30
5.0	7.5	10.0	2.5	5.0	7.5	20.0	2.5	5.0	7.5	9.9	2.5	5.0	35
5.2	7.8	10.4	12.9	15.5	18.2	20.8	23.4	25.9	28.5	31.1	33.7	36.4	40
5.4	8.0	0.7	3.4	6.1	8.8	1.5	4.2	6.8	9.5	2.2	4.8	7.6	45
5.6	8.3	1.1	3.9	6.7	9.5	2.3	5.0	7.8	30.6	3.4	6.2	8.8	150.0
5.7	8.6	1.5	4.3	7.2	20.1	2.9	5.8	8.7	1.6	4.5	7.3	40.2	55
5.9	8.9	1.9	4.8	7.8	0.7	3.7	6.7	9.6	2.6	5.6	8.5	1.5	60
6.1	9.2	12.3	15.3	18.3	21.4	24.4	27.5	30.6	33.6	36.6	39.7	42.8	65
6.3	9.5	2.6	5.8	8.9	2.1	5.2	8.3	1.5	4.6	7.7	40.9	4.1	70
6.5	9.7	3.0	6.2	9.4	2.7	5.9	9.2	2.4	5.6	8.9	2.1	5.5	175.0
6.7	10.0	3.3	6.7	20.0	3.3	6.7	30.0	3.3	6.7	40.0	3.3	6.6	80
6.9	0.3	3.7	7.1	0.6	4.0	7.4	0.9	4.2	7.7	1.2	4.5	8.0	85
7.0	10.5	14.1	17.6	21.2	24.6	28.2	31.7	35.2	38.7	42.2	45.7	49.3	90
7.2	0.8	4.5	8.1	1.6	5.2	8.8	2.5	6.2	9.7	3.3	7.0	50.5	95
7.4	1.1	4.9	8.5	2.2	5.9	9.6	3.4	7.1	40.8	4.4	8.2	1.9	200.0
7.8	1.7	5.6	9.5	3.4	7.2	31.1	5.0	8.9	2.8	6.7	50.5	4.4	10
8.1	2.2	6.3	20.4	4.4	8.5	2.6	6.7	40.8	4.8	8.8	3.0	7.1	20
8.5	12.7	17.1	21.3	25.6	29.8	34.1	38.4	42.6	46.8	51.1	55.4	59.6	30
8.9	3.3	7.7	2.2	6.6	31.1	5.6	40 0	4.4	8.8	3.3	7.8	62.1	40
9.2	3.9	8.5	3.1	7.8	2.4	7.0	1.7	6.4	50.9	5.6	60.2	4.8	250.0
9.6	4.5	9.3	4.1	8.9	3.7	8.5	3.4	8.2	2.9	7.8	2.7	7.4	60
10.0	5.0	20.0	5.0	30.0	5.0	9.9	5.0	50.0	5.0	60.0	4.9	70.0	70
10.4	15.6	20.7	25.9	31.1	36.3	41.4	46.7	51.9	57.0	62.2	67.4	72.5	80
0.8	6.1	1.4	6.8	2.2	7.6	3.0	8.3	3.8	9.1	4.4	9.8	5.2	90
1.1	6.7	2.2	7.8	3.3	8.8	4.4	50.0	5.6	61.1	6.8	72.2	7.9	300.0
1.5	7.2	2.9	8.6	4.4	40.2	5.9	1.8	7.4	3.1	8.8	4.5	80.4	10
1.9	7.8	3.6	9.6	5.5	1.4	7.4	3.3	9.3	5.2	71.1	7.0	3.0	20
12.2	18.3	24.4	30.6	36.6	42.8	48.8	55.0	61.2	67.2	73.3	79.4	85.6	30
2.6	8.9	5.2	1.4	7.7	4.1	50.5	6.7	2.9	9.2	5.5	81.8	8.2	40
3.0	9.5	5.9	2.4	8.8	5.3	1.8	8.3	4.8	71.3	7.8	4.2	90.8	350.0
3.3	20.0	6.6	3.3	9.9	6.6	3.4	60.0	6.8	3.3	80.0	6.8	3.3	60
3.7	0.6	7.4	4.3	41.1	7.9	4.8	1.6	8.5	5.3	2.1	9.0	6.0	70
14.1	21.2	28.2	35.2	42.2	49.2	56.3	63.3	70.3	77.4	84.3	91.5	98.5	80
4.4	1.6	8.8	6.1	3.3	50.6	7.8	5.0	2.3	9.4	6.6	3.9	101.1	90
4.8	2.2	9.6	7.1	4.4	1.8	9.2	6.7	4.1	81.5	8.9	6.3	3.6	400.0

TABLE 37.— *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

15	16	17	18	19	20	21	22	23	24	25	26	27	D'uble Areas
21.2	22.5	23.9	25.3	26.7	28.2	29.6	31.0	32.4	33.8	35.2	36.6	38.0	76.0
1.7	3.1	4.6	6.0	7.4	8.9	30.3	1.8	3.2	4.7	6.0	7.5	9.0	8
2.2	3.7	5.2	6.7	8.2	9.6	1.1	2.6	4.1	5.6	7.0	8.5	40.0	80.0
2.8	4.3	5.8	7.3	8.9	30.4	1.8	3.4	4.9	6.4	7.9	9.4	1.0	2
3.3	4.8	6.4	8.0	9.6	1.2	2.7	4.2	5.8	7.3	8.8	40.4	2.0	4
23.8	25.5	27.1	28.6	30.2	31.8	33.4	35.0	36.6	38.2	39.8	41.4	43.0	6
4.4	6.1	7.7	9.3	0.9	2.6	4.2	5.8	7.5	9.1	40.7	2.3	4.0	8
5.0	6.7	8.3	30.0	1.7	3.4	5.0	6.6	8.4	40.0	1.6	3.3	5.0	90.0
5.6	7.2	8.9	0.6	2.3	4.1	5.8	7.5	9.2	0.9	2.6	4.3	6.0	2
6.1	7.8	9.6	1.3	3.1	4.8	6.5	8.2	40.0	1.8	3.5	5.2	7.0	4
26.7	28.4	30.2	32.0	33.7	35.5	37.3	39.0	40.8	42.7	44.4	46.2	48.0	6
7.2	9.0	0.8	2.6	4.4	6.3	8.0	9.8	1.7	3.6	5.4	7.1	9.0	8
7.8	9.6	1.5	3.3	5.2	7.0	8.9	40.8	2.6	4.4	6.3	8.1	50.0	100.0
9.2	31.2	3.0	5.0	7.0	8.9	40.8	2.7	4.7	6.6	8.5	50.5	2.5	05
30.6	2.6	4.6	6.6	8.7	40.7	2.7	4.7	6.8	8.8	50.9	2.9	5.0	10
32.0	34.1	36.2	38.4	40.5	42.6	44.7	46.8	48.9	51.0	53.2	55.4	57.5	15
3.3	5.5	7.7	9.9	2.2	4.4	6.6	8.8	51.0	3.3	5.5	7.8	60.0	20
4.6	7.0	9.3	41.6	3.9	6.3	8.6	50.9	3.2	5.5	7.8	60.1	2.5	125.0
6.1	8.5	40.9	3.3	5.7	8.2	50.5	2.9	5.3	7.8	60.2	2.6	5.0	30
7.5	40.0	2.5	5.0	7.5	50.0	2.5	5.0	7.5	60.0	2.5	5.0	7.5	35
38.8	41.4	44.0	46.6	49.2	51.8	54.4	57.0	59.6	62.2	64.8	67.4	70.0	40
40.2	2.9	5.6	8.3	51.0	3.7	6.3	9.0	61.7	4.4	7.0	9.8	2.5	45
1.6	4.4	7.2	9.9	2.8	5.7	8.2	61.1	3.9	6.6	9.3	72.2	5.0	150.0
3.0	5.9	8.7	51.6	4.5	7.6	60.3	3.1	6.0	8.8	71.8	4.6	7.5	55
4.4	7.3	50.4	3.3	6.2	9.3	2.1	5.1	8.1	71.1	4.0	7.0	80.0	60
45.8	48.8	52.	55.0	58.0	61.0	64.2	67.1	70.3	73.4	76.2	79.3	82.5	65
7.2	50.5	3.5	6.6	9.8	3.0	6.0	9.2	2.3	5.5	8.7	81.8	5.0	70
8.6	1.8	5.0	8.3	61.5	4.8	8.0	71.2	4.6	7.7	81.0	4.3	7.5	175.0
50.0	3.3	6.6	60.0	3.3	6.8	9.9	3.2	6.7	80.0	3.2	6.7	90.0	80
1.4	4.8	8.1	1.6	5.0	8.5	71.9	5.3	8.8	2.2	5.6	9.0	2.5	85
52.8	56.2	59.8	63.3	66.8	70.4	73.8	77.3	80.9	84.3	87.9	91.7	95.0	90
4.0	7.8	61.3	5.0	8.7	2.1	5.7	9.4	3.0	6.7	90.2	3.9	7.5	95
5.5	9.2	2.9	6.7	70.3	4.0	7.7	81.4	5.1	8.9	2.8	6.4	100.0	200.0
8.3	62.1	6.0	70.0	3.8	7.8	81.7	5.5	9.4	93.4	7.2	101.2	05.0	10
61.0	5.1	9.3	3.2	7.4	81.5	5.5	9.5	93.7	7.8	101.9	06.0	10.0	20
63.9	68.0	72.4	76.6	80.9	85.2	89.4	93.7	98.0	102.2	106.5	110.8	115.0	30
6.5	71.0	5.5	9.9	4.3	8.9	93.2	7.8	102.2	106.8	11.1	15.5	20.0	40
9.4	4.0	8.6	83.2	7.9	92.5	7.1	101.9	06.5	11.1	15.9	20.5	25.0	250.0
72.1	7.0	81.8	6.5	91.4	6.5	101.2	06.0	10.7	15.5	20.4	25.3	30.0	60
5.0	80.0	5.0	90.0	4.9	100.0	05.0	10.0	15.1	20.0	25.0	30.0	35.0	70
77.8	82.9	88.1	93.2	98.4	103.8	108.9	114.1	119.2	124.5	129.5	134.8	140.0	80
80.6	5.9	91.2	6.5	102.1	07.4	12.9	18.1	23.5	28.9	34.3	39.8	45.0	90
3.2	8.9	4.4	100.0	05.7	11.1	16.8	22.2	29.7	33.3	38.9	44.5	50.0	300.0
6.0	91.8	7.5	03.3	09.2	14.8	20.6	26.3	32.1	37.9	43.5	49.3	55.0	10
9.0	4.7	100.9	06.8	12.7	18.6	24.3	30.3	36.2	42.2	48.1	54.1	60.0	20
91.5	97.7	103.9	110.0	116.1	122.2	128.3	134.5	140.6	146.8	152.8	158.9	165.0	30
4.5	100.7	07.1	13.2	19.6	26.0	32.2	38.5	44.9	51.1	57.2	63.8	70.0	40
7.2	03.8	10.2	16.7	23.2	29.7	36.2	42.5	49.1	55.5	62.0	68.5	75.0	350.0
100.0	06.6	13.4	20.0	26.8	33.3	40.0	46.6	53.2	60.0	66.8	73.4	80.0	60
02.8	09.6	16.4	23.2	30.2	37.0	43.8	50.7	57.5	64.5	71.2	78.1	85.0	70
105.6	112.5	119.6	126.8	133.8	140.8	147.8	154.8	161.8	168.9	175.9	183.0	190.0	80
08.2	15.5	22.9	30.0	37.2	44.3	51.7	58.9	66.1	73.4	80.5	87.8	95.0	90
11.1	18.5	25.9	33.3	40.7	48.1	55.6	63.0	70.4	77.8	85.2	92.6	200.0	400.0

TABLE 37. — *Continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

28	29	30	31	32	33	34	35	36	37	38	39	40	D'uble Areas
39.4	40.8	42.3	43.6	45.1	46.5	47.9	49.3	50.7	52.1	53.5	54.9	56.3	76.0
40.4	1.8	3.3	4.8	6.2	7.7	9.1	50.5	2.0	3.5	4.9	6.4	7.8	8
1.5	3.0	4.4	5.9	7.4	8.8	50.3	1.8	3.3	4.8	6.3	7.8	9.2	80.0
2.5	4.1	5.6	7.1	8.6	50.1	1.7	3.2	4.7	6.2	7.7	9.2	60.8	2
3.6	5.2	6.7	8.2	9.8	1.3	2.9	4.5	6.0	7.5	9.1	60.7	2.3	4
44.6	46.2	47.8	49.3	51.0	52.5	54.2	55.7	57.3	58.9	60.5	62.1	63.7	6
5.6	7.2	8.8	50.5	2.1	3.7	5.4	7.0	8.7	60.3	1.9	3.5	5.2	8
6.7	8.3	50.0	1.7	3.3	5.0	6.7	8.3	60.0	1.6	3.3	5.0	6.6	90.0
7.7	9.4	1.1	2.8	4.5	6.2	7.9	9.6	1.3	3.0	4.7	6.4	8.2	2
8.8	50.5	2.2	4.0	5.7	7.5	9.2	61.0	2.7	4.4	6.2	7.9	9.7	4
49.8	51.5	53.3	55.1	56.9	58.7	60.4	62.2	64.0	65.8	67.6	69.4	71.1	6
50.8	2.6	4.4	6.3	8.1	9.9	1.7	3.5	5.3	7.2	8.9	70.8	2.6	8
1.8	3.7	5.5	7.4	9.3	61.1	3.0	4.8	6.6	8.5	70.3	2.2	4.0	100.0
4.4	6.4	8.3	60.3	62.2	4.2	6.1	8.1	70.0	72.0	3.9	5.8	7.8	05
7.0	9.1	61.1	3.2	5.2	7.2	9.3	71.3	3.4	5.4	7.4	9.5	81.5	10
59.7	61.8	64.0	66.0	68.1	70.4	72.5	74.5	76.7	78.8	81.0	83.1	85.2	15
62.3	4.5	6.7	8.9	71.1	3.4	5.5	7.8	80.0	82.2	4.5	6.7	9.0	20
4.8	7.2	9.5	71.8	4.1	6.5	8.8	81.0	3.4	5.6	8.0	90.3	92.7	125.0
7.3	9.8	72.1	4.5	7.0	9.4	81.8	4.2	6.6	9.0	91.4	3.9	6.1	30
70.0	72.5	5.0	7.5	80.0	82.5	5.0	7.5	90.0	92.5	5.0	7.5	100.0	35
72.6	75.2	77.8	80.5	83.0	85.6	88.1	90.7	93.4	96.0	98.5	101.1	103.7	40
5.2	7.9	80.5	3.2	5.9	8.6	91.3	4.0	6.7	9.4	102.0	04.8	07.5	45
7.8	80.6	3.4	6.1	8.9	91.7	4.5	7.2	100.0	102.8	05.6	08.3	11.1	150.0
80.4	3.2	6.2	9.0	91.9	4.7	7.6	100.5	03.4	06.2	09.1	12.0	14.8	55
2.9	5.9	8.8	91.8	4.7	7.7	100.8	03.8	06.7	09.7	12.6	15.6	18.5	60
85.5	88.5	91.6	94.7	97.7	100.9	103.9	107.0	110.0	113.1	116.1	119.2	122.2	65
8.1	91.3	4.4	7.6	100.8	03.9	07.1	10.2	13.3	16.6	19.7	22.8	26.0	70
90.8	4.0	7.3	100.5	03.8	70.0	10.2	13.4	16.7	20.0	23.2	26.4	29.6	175.0
3.4	6.6	100.0	03.3	06.8	111.1	13.4	16.8	20.0	23.3	26.7	30.1	33.4	80
6.0	9.4	02.8	06.2	09.6	13.2	16.5	19.9	23.4	26.8	30.2	33.7	37.1	85
98.6	102.1	105.6	109.2	112.8	116.1	119.7	123.2	126.7	130.2	133.8	137.3	140.8	90
101.2	04.8	08.4	12.0	15.6	19.2	22.9	26.4	30.0	33.8	37.2	40.9	44.5	95
03.7	07.4	11.1	14.9	18.6	22.2	26.0	29.6	33.3	37.0	40.6	44.4	48.1	200.0
08.8	12.8	16.6	20.6	24.4	28.4	32.2	36.2	40.0	44.0	47.8	51.6	55.6	10
14.0	18.2	22.2	26.4	30.4	34.4	38.6	42.6	46.8	50.8	54.8	59.0	63.0	20
119.4	123.6	127.8	132.0	136.2	140.6	145.0	149.0	153.4	157.6	162.0	166.2	170.4	30
24.6	29.0	33.4	37.8	42.2	46.8	51.0	55.6	60.0	64.4	69.0	73.4	78.0	40
29.6	34.4	39.0	43.6	48.2	53.0	57.6	62.0	66.8	71.4	76.0	80.6	85.4	250.0
34.6	39.4	44.2	49.0	54.0	58.8	63.6	68.4	73.2	78.0	82.8	87.8	92.5	60
40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	200.0	70
145.2	150.4	155.6	161.0	166.0	171.2	176.2	181.4	186.8	192.0	197.0	202.2	207.4	80
50.4	55.8	61.0	66.4	71.8	77.2	82.6	88.0	93.3	98.8	204.0	09.6	14.6	90
55.6	61.2	66.8	72.2	77.8	83.4	89.0	94.4	200.0	205.6	11.2	16.6	22.2	300.0
60.8	66.4	72.4	78.0	83.8	89.4	95.2	201.0	06.8	12.4	18.2	24.0	29.6	10
65.8	71.8	77.6	83.6	89.4	95.4	201.6	07.6	13.6	19.4	25.2	31.2	37.0	20
171.0	177.0	183.2	189.4	195.4	201.8	207.8	214.0	220.0	226.2	232.2	238.4	244.4	30
76.2	82.6	88.8	95.2	201.6	07.8	14.2	20.4	26.7	33.2	39.4	45.6	52.0	40
81.6	88.0	94.6	201.0	07.6	14.0	20.4	26.8	33.4	40.0	46.4	52.8	59.2	350.0
86.8	93.2	200.0	06.6	13.6	22.2	26.8	33.6	40.0	46.6	53.4	60.2	66.8	60
92.0	98.8	05.6	12.4	19.2	26.4	33.0	39.8	46.8	53.6	60.4	67.4	74.2	70
197.2	204.2	211.2	218.4	225.6	232.2	239.4	246.4	253.4	260.4	267.6	274.6	281.6	80
202.4	09.6	16.8	24.0	31.2	38.4	45.8	52.8	60.2	67.6	74.4	81.8	89.0	90
07.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.6	74.0	81.4	88.8	96.2	400.0

TABLE 37. — *Continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

41	42	43	44	45	46	47	48	49	50	75	100		D'ubl Areas
57.7	59.2	60.6	61.9	63.4	64.8	66.2	67.6	69.0	70.4	105.7	140.7	—	76.0
9.2	60.7	2.1	3.6	5.0	6.4	7.8	9.3	70.7	2.3	08.4	44.4	—	8.0
60.8	2.2	3.7	5.2	6.7	8.2	9.7	71.2	2.6	4.1	11.2	48.1	—	80.0
2.2	3.8	5.3	6.8	8.3	9.8	71.4	2.9	4.4	5.9	14.0	51.8	—	2
3.8	5.4	6.9	8.4	70.0	71.6	3.2	4.7	6.2	7.8	16.8	55.5	—	4
65.3	66.8	68.4	70.1	71.7	73.3	74.8	76.4	78.0	79.6	119.5	159.2	—	6
6.8	8.4	70.1	1.7	3.4	5.0	6.6	8.3	9.8	81.5	22.3	63.0	—	8
8.4	70.0	1.7	3.3	5.0	6.7	8.4	80.0	81.7	3.4	25.1	66.7	—	90.0
9.8	1.6	3.3	4.9	6.7	8.4	80.1	1.8	3.5	5.2	27.9	70.6	—	2
71.4	3.2	4.8	6.6	8.4	80.2	1.9	3.6	5.3	7.1	30.7	74.1	—	4
72.8	74.7	76.4	78.2	80.0	81.8	83.6	85.3	97.1	88.9	133.4	177.7	—	6
4.4	6.3	8.1	9.9	1.7	3.5	5.3	7.2	8.9	90.8	36.2	81.6	—	8
5.9	7.7	9.7	81.4	3.3	5.2	7.0	8.8	90.7	2.6	38.9	85.1	—	100.0
9.8	81.7	83.6	5.6	7.5	9.4	91.4	93.4	95.3	7.2	45.9	94.4	—	05
83.5	5.6	7.6	9.6	91.7	93.7	5.7	7.8	9.8	101.9	52.8	203.7	—	10
87.3	89.4	91.6	93.7	95.8	97.9	100.1	102.2	104.4	106.5	159.8	212.9	—	15
91.2	93.4	5.6	7.8	100.0	102.2	04.5	06.7	08.9	11.8	66.7	22.2	—	20
5.0	7.3	9.7	101.9	04.2	06.5	08.9	11.2	13.5	15.6	73.7	31.4	—	125.0
8.8	101.2	103.6	05.9	08.4	10.7	13.1	15.5	17.9	20.2	80.5	40.7	—	30
102.5	05.0	07.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	87.5	50.0	—	35
106.3	108.9	111.5	114.2	116.7	119.3	121.9	124.4	127.1	129.8	194.5	259.2	—	40
11.2	12.9	15.5	18.2	20.8	23.6	26.2	28.9	31.7	34.3	201.5	68.5	—	45
14.0	16.7	19.5	22.3	25.0	27.8	30.6	33.4	36.2	38.9	08.5	77.7	—	150.0
17.8	20.6	23.5	26.3	29.2	32.1	34.9	37.8	40.8	43.6	15.4	87.0	—	55
21.5	24.5	27.4	30.4	33.4	36.4	39.4	42.3	45.2	48.2	22.4	96.3	—	60
25.3	128.4	131.5	134.4	137.6	140.6	143.8	146.8	149.8	152.8	229.3	305.5	—	65
129.1	32.3	35.4	38.5	41.7	44.9	48.0	51.2	54.3	57.4	36.2	14.8	—	70
32.9	36.1	39.4	42.5	45.8	49.0	52.2	55.5	58.8	62.0	43.0	24.0	—	175.0
36.8	40.0	43.4	46.8	50.0	53.4	56.8	60.0	63.4	66.8	50.0	33.3	—	80
40.5	43.9	47.4	50.8	54.2	57.7	61.0	64.5	67.9	71.4	56.9	42.6	—	85
144.4	147.8	151.4	154.9	158.4	161.9	165.4	168.9	172.4	176.0	263.9	351.8	—	90
48.1	51.8	55.3	58.9	62.5	66.2	69.8	73.4	77.0	80.5	70.8	61.1	—	95
51.8	55.6	59.3	63.0	66.8	70.4	74.1	77.8	81.4	85.2	77.7	70.3	—	200.0
59.5	63.4	67.3	71.1	75.0	78.9	82.8	86.7	90.5	94.5	91.6	88.9	—	10
67.0	71.2	75.2	79.3	83.4	87.5	91.5	95.6	99.7	203.7	305.5	407.4	—	20
174.7	178.9	183.3	187.5	191.8	196.0	200.1	204.4	208.8	213.0	319.4	425.9	—	30
82.2	86.8	91.1	95.5	200.0	204.5	08.8	13.3	17.8	22.2	33.3	44.4	—	40
89.8	94.5	99.0	203.7	08.3	13.0	17.5	22.2	26.8	31.5	47.1	62.9	—	250.0
97.4	202.3	207.0	11.9	16.6	21.6	26.3	31.1	36.0	40.8	61.0	81.5	—	60
205.0	10.0	15.0	20.0	25.0	230.0	35.0	40.0	45.0	50.0	75.0	500.0	—	70
212.7	217.8	223.0	228.2	233.3	238.6	243.7	248.9	254.1	259.2	388.7	518.5	—	80
20.2	25.6	30.9	36.3	41.7	47.1	52.4	57.8	63.2	68.5	402.7	37.0	—	90
27.8	33.4	38.9	44.5	50.0	55.6	61.1	66.7	72.3	77.8	16.5	55.5	—	300.0
35.4	41.2	46.9	52.6	58.3	64.2	69.8	75.6	81.3	87.0	30.4	74.0	—	10
43.0	49.0	54.8	60.8	66.7	72.7	78.5	84.4	90.4	96.3	44.3	92.6	—	20
250.6	256.7	262.8	268.9	275.0	281.2	287.2	293.3	299.5	305.5	458.2	611.0	—	30
58.2	64.5	70.7	77.1	83.3	89.7	95.9	302.2	308.5	14.8	72.1	29.6	—	40
65.7	72.3	78.7	85.2	91.7	98.2	304.6	11.1	17.6	24.1	85.9	48.1	—	350.0
73.3	80.1	86.7	93.4	300.0	306.8	13.3	20.0	26.7	33.0	99.8	66.0	—	60
80.9	87.9	94.6	301.5	08.3	15.3	22.0	28.9	35.8	42.6	513.7	85.2	—	70
288.5	295.6	302.6	309.7	316.7	323.8	330.7	337.8	344.8	351.8	527.6	703.6	—	80
96.1	303.4	10.5	17.8	20.0	32.3	339.4	46.7	53.9	61.1	41.5	22.2	—	90
303.7	11.1	18.5	25.9	33.3	40.7	48.1	55.5	62.9	70.3	55.5	40.6	—	400.0

TABLE 38. CONVERSION TABLE, LINEAL FEET TO MILES

1 to 9		10–90		100–900		1000–9000		10,000–90,000	
Feet	Miles	Feet	Miles	Feet	Miles	Feet	Miles	Feet	Miles
1	0.00019	10	0.00189	100	0.01894	1000	0.18939	10,000	1.8939
2	0.00038	20	0.00379	200	0.03788	2000	0.37879	20,000	3.7879
3	0.00057	30	0.00568	300	0.05682	3000	0.56818	30,000	5.6818
4	0.00076	40	0.00758	400	0.07576	4000	0.75758	40,000	7.5758
5	0.00095	50	0.00947	500	0.09470	5000	0.94697	50,000	9.4697
6	0.00114	60	0.01136	600	0.11364	6000	1.13636	60,000	11.3636
7	0.00132	70	0.01326	700	0.13258	7000	1.32576	70,000	13.2576
8	0.00152	80	0.01515	800	0.15152	8000	1.51515	80,000	15.1515
9	0.00171	90	0.01705	900	0.17046	9000	1.70455	90,000	17.0455

Overhaul.

If dirt must be hauled more than a stated distance (free haul) to place it in fill, the additional distance is called overhaul and is paid for at an agreed rate; the amount of overhaul is estimated as the (number of cubic yards that have to be overhauled) × (the distance beyond the free haul expressed in stations, that is units of 100 ft.). That is, if 20 cu. yds. had to be hauled 3,000 ft. when the free haul was 2,000 ft., the overhaul would be expressed as 10 stations × 20 yds.

Overhaul is to be avoided if possible, as it is a source of dispute between Contractor and Engineer. Where necessary it can often be computed from an inspection of the earthworks computation sheets. If the cut from which the dirt is drawn is short and well defined and the fill to which it is taken is likewise well defined, the position of the centers of gravity of both cut and fill can be located sufficiently close by inspection; however, if two or three cuts are hauled to one fill or one cut to more than one fill, the amount and length of overhaul can only be determined with accuracy by means of a mass diagram.

In Fig. 64 an earthwork chart is given which was prepared for the Batavia-Buffalo road, State Route 6, Sections 10 and 11. This chart gives amount, location, direction, and length of haul for excavation at a glance, and as an example of overhaul has been illustrated on the diagram this will indicate the method.

Explanation of Fig. 64, page 253.

1. The horizontal scale represents stations along road: in this case 5 stations or 500 ft. to the inch.
2. The vertical scale represents the algebraic sum of the excavation and embankment on whose vertical the amount is plotted. In this case 200 cu. yds. to the inch.
3. Reading from left to right, all ascending lines indicate amount and location of excavation; all descending lines indicate amount and location of embankment.
4. All embankment quantities in each balancing section were multiplied by the factor written above that section as "Balance Used."
5. The excavation and embankment quantities at each station were added together algebraically, after the embankment quantities had been increased as specified; the algebraic sum so obtained was then added algebraically to the sum similarly obtained from previous sections.
6. This diagram indicates the amount of material that should be excavated or deposited at each station.
7. The diagram indicates the direction of haul.
8. To compute overhaul consider the section *A B C D E A*. Suppose free haul is to be 500 ft. Find where a line 500 ft. long will fit the section. *B D* is such a line. The material above *B D* will be hauled free.

On material *A B* there will be paid overhaul. The average distance the material *A B* will be hauled will be the distance between the centers of gravity of *A B* and *D E* respectively.

Let X represent that distance. Then X minus 500 ft. equals the average length of overhaul.

9. The overhaul can also be computed from the area of the section *A B D E A;* this area represents the product of the material excavated in yards and the distance hauled. Find the area of the section *A B D E A* by a planimeter or otherwise. This area will be expressed as yard stations, and when divided by the ordinate *G B* in cubic yards will give the length of haul in stations.

Suppose the area *A B D E A* equals 2.5 square inches. Each square inch represents 200 cu. yds. *X* 5 stations, or 1,000 sta. yds. Therefore, an area of 2.5 square inches would represent 2,500 sta. yds. According to the diagram the total amount of dirt hauled equals 280 cu. yds. as measured on the ordinate *GB*. Therefore the average haul for this 280 cu. yds. equals $\frac{2{,}500 \text{ sta. yds.}}{280 \text{ cu. yds.}} = 8.9$ stations.

The free haul equals 500 feet, or 5 stations, therefore the overhaul equals $8.9 - 5 = 3.9$ stations. The amount of overhaul equals 280 cu. yds. $\times\ 3.9 = 1092$ sta. yds.

TABLE 39.[1] GIVING THE NUMBER OF POUNDS OF STONE PER 100 FEET OF ROAD FOR DIFFERENT DEPTHS OF LOOSE SPREAD AND DIFFERENT WEIGHTS OF STONE

12–FOOT ROAD

Weight of 1 cu. yd. Stone, Loose Measure	Depth of Loose Spread				
	$2\frac{1}{2}''$	$3\frac{1}{8}''$	$3\frac{7}{8}''$	$5\frac{1}{4}''$	$6\frac{1}{2}''$
2250	20,800	26,000	32,300	43,700	54,200
2300	21,300	26,600	33,000	44,700	55,300
2350	21,800	27,100	33,700	45,700	56,600
2400	22,200	27,700	34,400	46,700	57,800
2450	22,700	28,200	35,200	47,700	59,000
2500	23,200	28,800	35,900	48,700	60,200
2550	23,600	29,400	36,600	49,600	61,400
2600	24,100	30,000	37,300	50,600	62,600

[1] NOTE. — The quantities in this table are figured by slide rule but are sufficiently close for the purpose to which the table is put.

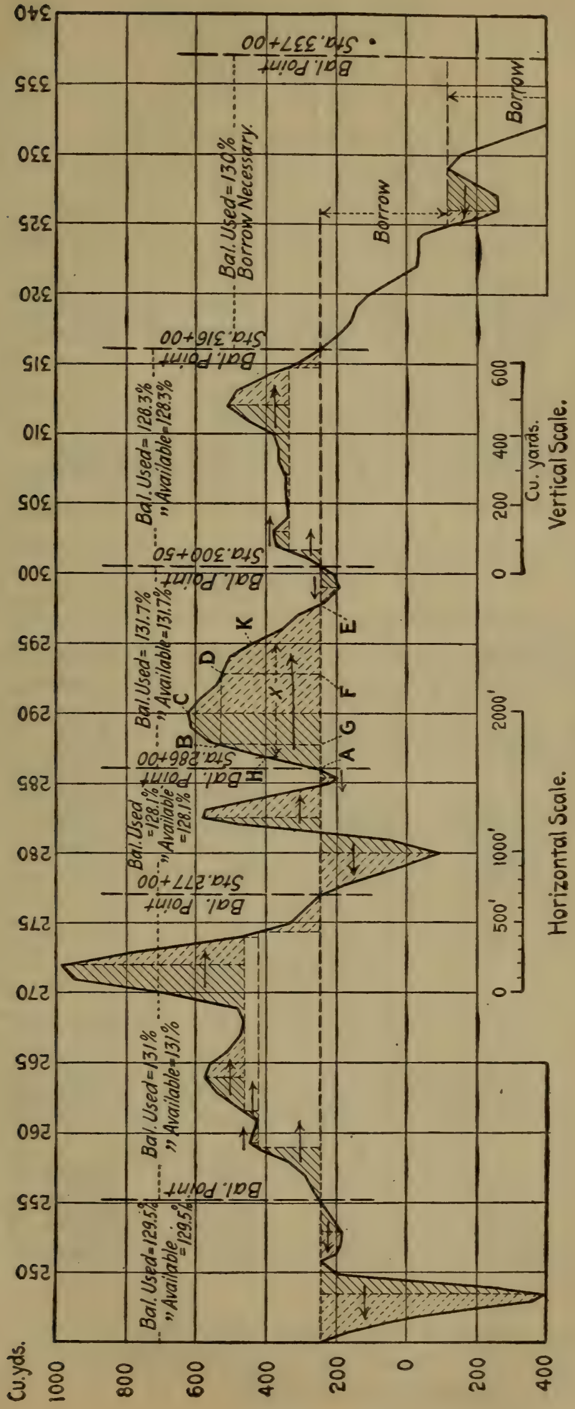

Cu. yds.
Bal. Used = 129.5%
" Available = 129.5%
Bal. Point
Bal. Used = 131%
" Available = 131%
Bal. Point
Sta. 277+00
Bal. Used = 128.1%
" Available = 128.1%
Bal. Point
Sta. 286+00
Bal. Used = 131.7%
" Available = 131.7%
Bal. Point
Sta. 300+50
Bal. Used = 128.3%
" Available = 128.3%
Bal. Point
Sta. 316+00
Bal. Used = 130%
Borrow Necessary.
Bal. Point
Sta. 337+00
Borrow
Borrow
A B C D E F G H K X
Horizontal Scale.
Vertical Scale.
Cu. yards.

FIG. 64

TABLE 39. — *Continued*

Weight of 1 cu. yd. Stone, Loose Measure	Depth of Loose Spread				
	2½″	3⅛″	3⅞″	5¼″	6½″
14-FOOT ROAD					
2250	24,300	30,400	37,700	51,000	63,200
2300	24,800	31,000	38,500	52,200	64,600
2350	25,400	31,700	39,300	53,300	66,100
2400	25,900	32,400	40,200	54,400	67,500
2450	26,400	33,000	41,000	55,600	68,900
2500	27,000	33,700	41,800	56,700	70,300
2550	27,600	34,400	42,700	57,800	71,600
2600	28,100	35,100	43,500	59,000	73,000
15-FOOT ROAD					
2250	26,000	32,600	40,400	54,700	67,700
2300	26,600	33,200	41,300	55,900	69,200
2350	27,200	34,000	42,200	57,200	70,800
2400	27,800	34,700	43,100	58,400	72,200
2450	28,400	35,400	44,000	59,600	73,800
2500	29,000	36,100	44,800	60,800	75,200
2550	29,500	36,900	45,800	62,000	76,700
2600	30,100	37,600	46,700	63,200	78,200
16-FOOT ROAD					
2250	27,800	34,700	43,100	58,400	72,300
2300	28,400	35,500	44,000	59,600	73,900
2350	29,000	36,300	45,000	60,900	75,500
2400	29,600	37,000	45,900	62,200	77,200
2450	30,200	37,800	46,900	63,600	78,700
2500	30,900	38,600	47,800	64,900	80,300
2550	31,500	39,400	48,800	66,200	82,000
2600	32,100	40,100	49,800	67,400	83,600

The computation of earthwork is the longest operation of the quantity estimate. When this is finished the quantity estimate is considered as practically complete.

TABLE 40. GIVING THE NUMBER OF CUBIC YARDS OF MACADAM PER 100 FEET OF ROAD FOR DIFFERENT WIDTHS AND DEPTHS

Width of Macadam	Depth							
	2″	2½″	3″	3½″	4″	5″	6″	7″
10′	6.17	7.71	9.26	10.80	12.34	15.43	18.52	21.61
12′	7.41	9.26	11.11	12.96	14.82	18.52	22.22	25.93
14′	8.64	10.80	12.96	15.12	17.28	21.61	25.92	30.25
15′	9.26	11.58	13.89	16.20	18.52	23.16	27.78	32.41
16′	9.88	12.35	14.81	17.28	19.76	24.70	29.63	34.57
18′	11.11	13.90	16.67	19.44	22.22	27.79	33.34	38.89
20′	12.35	15.44	18.52	21.60	24.70	30.87	37.04	43.21
22′	13.58	16.98	20.37	23.76	27.16	33.96	40.74	47.53

The other quantities figured are: length of road in miles. Table 38 converts lineal feet to miles.

Quantities of macadam, sub-base, concrete paving foundations, square yards of resurfacing, which are simple computations involving length, width, and depth: Tables 39, 40, and 41 can be conveniently used.

Quantities of oil or other surface or penetration treatments, which are usually specified as gallons, per square yard: Table 42 is developed with this in view.

Concrete for culverts or retaining walls. Where a large amount of work is done it generally pays to compile a table of quantities for standard culverts of different sizes and lengths. The quantities can then be picked from these tables sufficiently close for a preliminary estimate. There would be no object in including in a book of this character any table suitable for certain culverts, as each department has a different standard.

Expanded metal and reinforcing bars, Tables 15 and 16 cover these features.

Weights of cast-iron pipe: Table 14 can be used.

Incidentals requiring ordinary arithmetical computations only.

The quantity estimated being completed, the estimate of cost is made. This is considered in chapter X.

Final Design Report

On the completion of the design a report of this nature is filed for reference.

Rochester, January 31, 1916

REPORT ON DESIGN AND ESTIMATE
of the
VARYSBURG–WARSAW PART II COUNTY HIGHWAY
No. 1349
WYOMING COUNTY
(FORMERLY known as the Orangeville-Warsaw Road)
Length, 4.74 *Miles*

Type of Construction. *Top:* From Orangeville Center to Corporation line Village of Warsaw (Sta. 0 + 00 — 249 + 57) 3″ waterbound macadam 14′ wide. Imported limestone top and screenings, surface application of calcium chloride using $2\frac{1}{2}$# per sq. yd. in two applications.
Bottom: Orangeville Center Sta. 0+00 to corporation line Village Warsaw Sta. 249=57, 5″ macadam 14′ wide. Screened gravel local. Section 26′ wide with 18″ ditch.

Estimated Cost........................	$49,858.00
Engineering and Contingencies..........	5,042.00
	$54,900.00
Cost per Mile......................	$11,600.00

Survey. By H. TenHagen, rodman, Spring, 1915. Weather conditions favorable.
Design. By F. W. Mills, Leveler.
Field Inspection. By George A. Wellman, County Assistant; F. W. Mills, Leveler.
Estimate. By George A. Wellman, County Assistant; George G. Miller, Chief Draughtsman.
Status and Connections. This road is a section of the old Cherry Valley Trail which is claimed to be the shortest highway between Buffalo and New York. It is the beginning of a system of improvements to connect the western part of Wyoming County with Warsaw. At Halls Corners (Sta. 145 + 00) it will connect by a proposed County System road with the east end of C. H. 1267. With the proposed Varysburg-Warsaw Part I Road and proposed Route 19 it will connect with Route 16 already built. It will also connect with the proposed County System road south through Johnsonburg, North Java, to Arcade.
Foundation Soil. Is for the most part clay loam and is very unstable when wet. This calls for an unusual estimate for sub-base.
Traffic. The heaviest traffic is eastward and down hill. It consists principally of wagon hauled farm traffic. There is considerable automobile traffic both ways. This will greatly increase as the highways West towards Buffalo are improved.
Grades. The ruling grade for eastbound traffic is 8% between Sta. 23+00 and 29+00. The ruling grade in the opposite direction is a short 8.54% at Sta. 149.

Alignment. The alignment is generally straight and curves easy. The minimum radius is 573′ at Sta. 162+00.

Right of Way. No land taking is necessary.

Type of Metaling. The bottom course throughout the entire length of the road is to be of screened gravel as per B. R. sample G–2095 5″ deep, to be obtained on the property of Henry Roth, one mile south of Sta. 145+00.

Top course is to be 3″ imported limestone from Buffalo Crushed Stone Co. with screenings from same source.

Drainage. All existing culverts have been replaced by either concrete or cast-iron pipe structures. The former have been given preference wherever head room permitted.

The bridge at Sta. 15+40 is to be rebuilt by the Town of Orangeville and that at Sta. 175+19 by the Town of Warsaw.

Materials

The materials suitable to be used in the work have all been tested and accepted by the Department. The filler for the bottom course to be the fine material screened out at the pit.

Sand for use in concrete has been accepted from the Roth pit, one mile south of Sta. 145+00.

Unloading Points. Erie R. R. at Warsaw Station siding, 1200′ from Sta. 249+57.

Respectfully submitted,
Perry Filkin,
Division Engineer

Construction Plans. The construction plans should give sufficient information to show the contractor what he is expected to do and to enable the constructing engineer to stake out and to build the road.

A finished set of plans consist of a map, profile, and cross-sections showing the alignment in relation to the preliminary survey line, the proposed grade elevations, the shape of the finished road, the widths

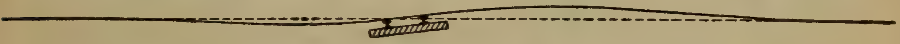


FIG. 65

and depths of road metaling, the crowns to be used, the existing structures and the proposed structures, and all the minor points of design. Each Department has its own method of giving this information, and it makes little difference how it is shown so long as it is complete and clear. In general it may be said that the scales used are the same

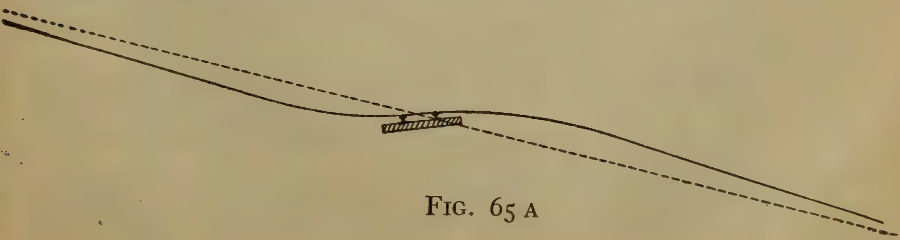


FIG. 65 A

as in mapping the preliminary survey and that the size of sheets or rolls must be convenient to handle in the field; sheets larger than 24″×30″ are clumsy.

Miscellaneous Points. A point often overlooked in lying a grade line is the proper approach to a railroad grade crossing where the track is on a curve and has a superelevated rail. Where the road grade is level, or nearly level, the solution is comparatively simple, as shown in Fig. 65; but where the grade of the road is in an opposite direction to the elevation of the rail it is more difficult and sometimes impossible to make an easy riding crossing.

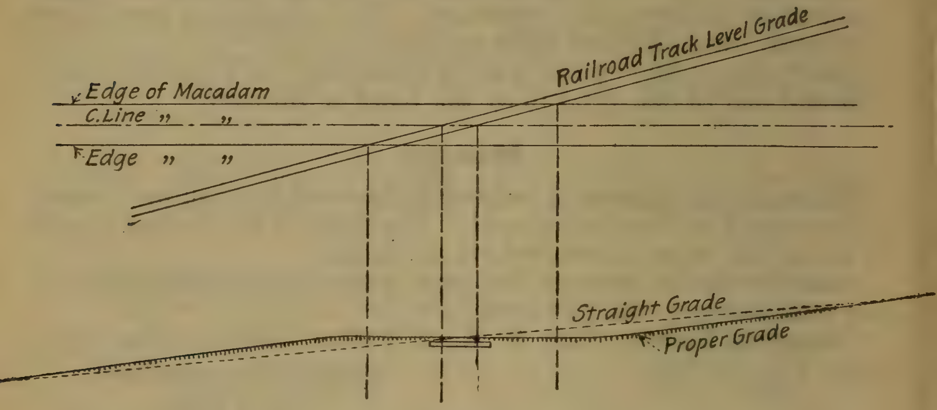


Fig. 66

Also, where a road, on a steep grade, crosses the railroad track on a large skew angle, care must be taken to flatten the grade near the track to avoid distorting the road section due to the difference in the rate of grade of the track and road. See Fig. 66.

Grade Crossing Eliminations. In grade crossing elimination designs the following minimum clearances have been adopted, Div. 5, N. Y. S. Dept. of Highways.

Where a highway is to be built under a railroad the crown elevation is made 13.5′ below the bottom of the bridge girder, and the minimum right-angle distance between abutments is taken as 26 feet. For solid floor railroad through girder bridges a clearance of 13.5′ below the bottom of the girder means a distance of from 16.5′ to 17.0′ below the top of the rail.

The tables (pp. 259, 260) are taken from Spofford's "Theory of Structures," and a pamphlet issued by Heath & Milligan, of Chicago. They show the approximate weight of through girder railway bridges with the depth of floor system. They are useful for preliminary estimates of grade-crossing elimination.

The weights given are for the steel only; the weight of the floor system must be added. For purposes of a rough preliminary estimate of cost the superstructure can be assumed to cost $60.00 per ton in place including all erection costs.

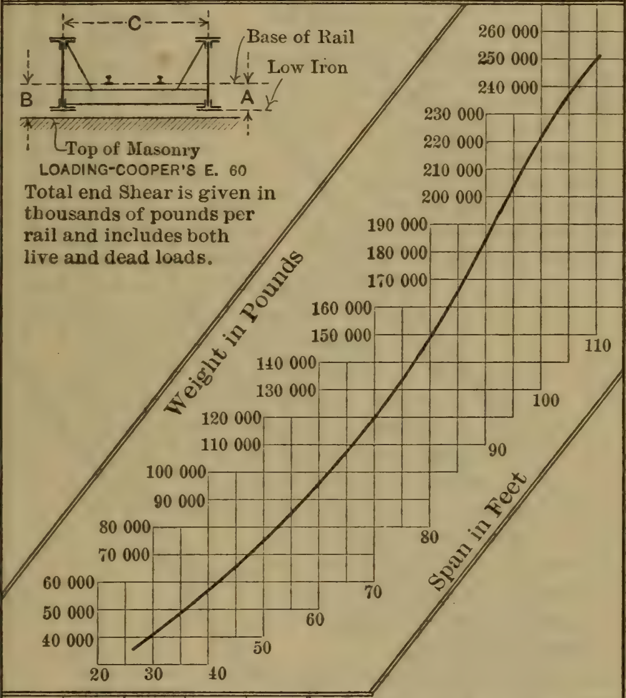
Where the highway crosses over the railroad a minimum clearance of 21.0′ is used from the top of rail to the bottom of the highway

bridge; the span varies with the number of tracks. In determining the length required it is best to get in touch with the railroad engineers.

Right of Way Computations. The form of traverse computation and closure was shown on page 155.

The areas of rights of way are generally figured by dividing the parcel into rectangles, trapezoids, triangles, sectors, or segments, and figuring these shapes from the formulæ given in Table 57. These areas are checked by planimeter. They are usually figured to the nearest 0.01 acre.

THROUGH PLATE GIRDER SPANS, I-BEAM FLOOR
WEIGHTS, DIMENSIONS, ETC.



Span	Total End Sh.	A	B	C
30 ft.	106.2	2'-2"	2'-2"	15'-0"
35 "	117.1	"	"	16-0
40 "	128.7	"	"	17-0
45 "	141.1	2-2½	2-2½	17-6
50 "	152.2	"	"	"
55 "	162.1	2-3	2-9	"
60 "	173.2	"	"	"
65 "	186.2	"	"	"
70 "	199.3	2-3½	3-9	"
75 "	212.5	"	3-10½	"
80 "	226.4	"	"	"
85 "	240.5	"	"	"
90 "	257.4	"	"	"
95 "	268.7	"	"	"
100 "	284.0	2-4	"	"
110 "	306.0	2-4½	"	"

Erector's Note:
W = Total weight of one single track span with two light girders.

Span	Weight of one light girder	Weight of one heavy girder	Weight of one floor system
30' to 50'	.22 W	.39 W	.56 W
55' " 80'	.27 W	.48 W	.47 W
85' " 110'	.31 W	.57 W	.38 W

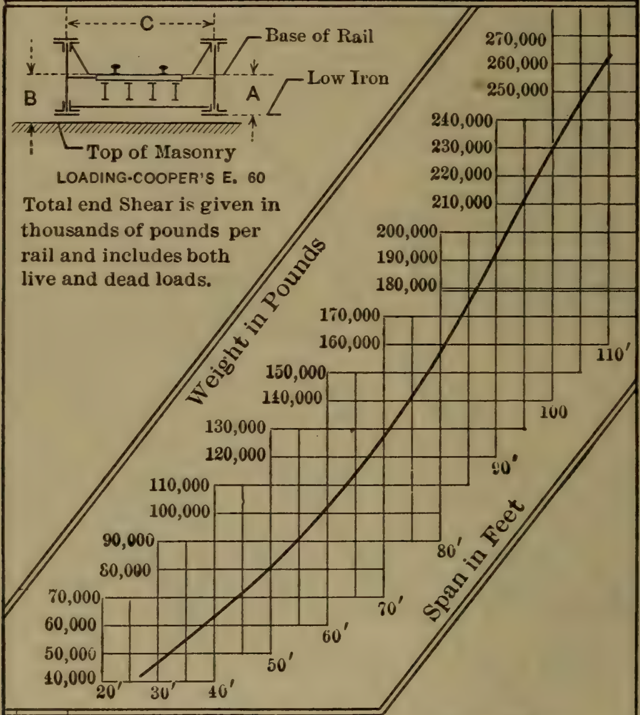
The method of double-meridian distances can, however, be used if desired. The following formula and example are given to illustrate this method. It is not often necessary and is a tedious computation:

The rule is:

Twice the area of the figure is equal to the algebraic sum of the products of the double-meridian distances of each course multiplied by its latitude.

In which the double-meridian distance equals the sum of the meridian distances of the two ends of each course referred to the

THROUGH PLATE GIRDER SPANS, STRINGER FLOOR.
WEIGHTS, DIMENSIONS, ETC.



Span	Total End Sh.	A	B	C
30 Ft.	108.7	3′3″	3′3″	15′6″
35 "	121.0	3′3½″	3′3½″	16′6″
40 "	133.2	"	"	17′6″
45 "	144.7	"	"	"
50 "	156.0	"	"	"
55 "	167.5	3′4″	3′11″	"
60 "	176.3	"	"	"
65 "	191.1	3′4½″	"	"
70 "	204.7	"	"	"
75 "	220.4	"	5′0″	"
80 "	232.8	"	"	"
85 "	248.6	"	"	"
90 "	262.3	3′5″	"	"
95 "	277.4	"	"	"
100 "	291.2	3′6″	"	"
110 "	319.6	"	"	"

Erector's Note.
W = Total weight of one single track span with two light girders.

Span	Weight of one light girder.	Weight of one heavy girder.	Weight of one floor system.
30′ to 50′	.24 W	.42 W	.52 W
55′ to 80′	.25 W	.46 W	.50 W
85′ to 110′	.28 W	.51 W	.44 W

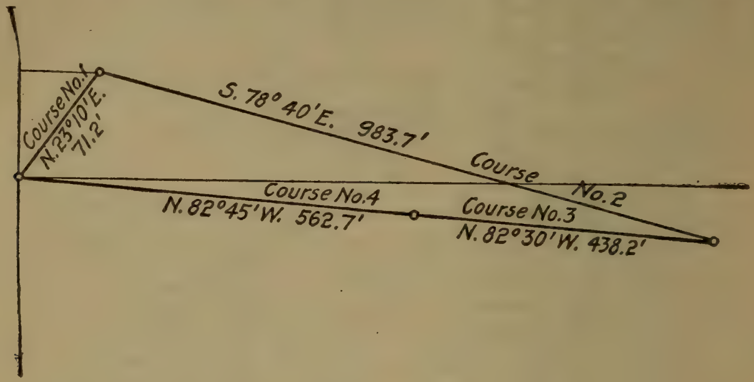
Example of Double-meridian distance Area Computation of the Parcel shown in Fig. 50, page 155. And figure on page 262.

Course Number	Bearing	Dist.	N	S	E	W	Lat.	D. M. D.	+ Areas	– Areas
1	N 23° 10′ E . . .	71.2	65.4	—	28.0	—	+ 65.4	28.0	1,831	—
2	S 78° 40′ E . . .	983.7	—	193.3	964.5	—	– 193.3	1020.5	—	197,263
3	N 82° 30′ W . . .	438.2	57.2	—	—	434.5	+ 57.2	1550.5	88,688	—
4	N 82° 45′ W . . .	562.7	71.0	—	—	558.2	+ 71.0	558.2	39,632	—

197,263 sq. ft. – 130,151 sq. ft. = 67,112 sq. ft.
This equals twice the area of the parcel.

$$\text{Area of parcel} = \frac{67112}{2 \times 43{,}560} = 0.770 \text{ acres.}$$

meridian drawn through the most westerly point of the parcel, and the latitude of each course is reckoned as plus if the course runs north and minus if it runs south. Take as an example the right of way parcel shown in Fig. 50, page 155, for which the traverse has been figured and refer the meridian distances to the meridian drawn through the corner 3.1′ distant from station 194+71.7.

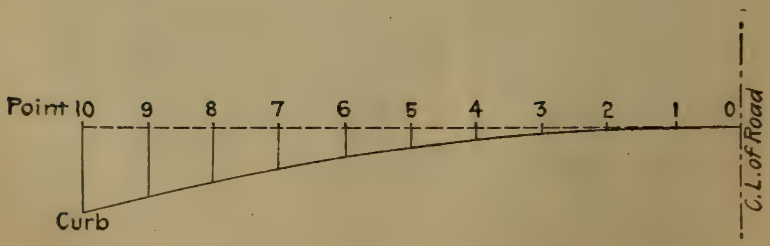


Parabolic Crowns for Pavements.

It is often convenient to have the following data on parabolic crown ordinates in making templets for pavement work.

Divide the distance from the center of the road to the curb or edging into ten equal parts and call the total crown 1.0; the distance down to the surface of the pavement from the crown elevation at each of these ten points expressed in terms of the total crown will be

Center of Road, point No.	0	0.00
	1	0.01
	2	0.04
	3	0.09
	4	0.16
	5	0.25
	6	0.36
	7	0.49
	8	0.64
	9	0.81
Curb point	10	1.00



Summary of Points to be Considered in Making an Economical Design

Justifiable economy in grading is limited to the intermediate grades and to variations in the cross-sections. A well designed road in these particulars may easily save $700 to $900 per mile over a careless design.

Economy in widths of hard paving is attained by the selection of a width suitable to each particular road or part of road. A uniform width of 16 ft. for all roads is unnecessary and a waste of money both in first cost and in maintenance and renewal. For class I and II traffic nothing less than 15′ to 16′ should be considered; for class III and IV the widths may vary from 10′ up. The cost per ft. width per mile for different types is approx. as follows:

Type of Road	First Cost per foot width per mile.
Brick	$1200
Asphalt	1100
Concrete	700
Bituminous Macadam	600
Waterbound "	500

Economy in foundations is limited to utilizing local materials to their best advantage with short hauls.

Economy in top courses lies in the selection of the cheapest type suitable to the traffic conditions and the use of the minimum thickness.

Economy in maintenance is attained by preventing rather than by repairing damage.

TABLE 41

SQUARE YARDS PER 100 FEET AND PER MILE FOR DIFFERENT WIDTH OF SURFACE

Width in Feet	Number of Square Yards		Width in Feet	Number of Square Yards	
	Per 100 Feet	Per Mile		Per 100 Feet	Per Mile
8	88.889	4,693	26	288.889	15,253
10	111.111	5,867	28	311.111	16,427
12	133.333	7,040	30	333.333	17,600
14	155.556	8,213	32	355.556	18,773
15	166.667	8,800	34	377.778	19,947
16	177.778	9,387	36	400.000	21,120
18	200.000	10,560	38	422.222	22,293
20	222.222	11,734	40	444.444	23,466
22	244.444	12,907	42	466.667	24,640
24	266.667	14,080	44	488,889	25,813

TABLE 42. GALLONS PER 100′ OF ROAD FOR DIFFERENT WIDTHS AND RATES OF APPLICATION

Width in Feet	Number of Gallons to the Square Yard											
	0.1	0.2	0.25	0.3	0.33⅓	0.4	0.5	0.6	0.66⅔	0.7	0.8	0.9
8	8.89	17.78	22.22	26.67	29.63	35.56	44.44	53.33	59.26	62.22	71.11	80.00
10	11.11	22.22	27.77	33.33	37.04	44.44	55.56	66.67	74.08	77.78	88.89	100.00
12	13.33	26.67	33.33	40.00	44.45	53.33	66.67	80.00	88.89	93.33	106.67	120.00
14	15.56	31.11	38.89	46.67	51.85	62.22	77.78	93.33	103.71	108.89	124.44	140.00
15	16.67	33.33	41.67	50.00	55.56	66.67	83.33	100.00	111.11	116.67	133.33	150.00
16	17.78	35.56	44.44	53.33	59.26	71.11	88.89	106.67	118.52	124.44	142.22	160.00
18	20.00	40.00	50.00	60.00	66.67	80.00	100.00	120.00	133.33	140.00	160.00	180.00
20	22.22	44.44	55.56	66.67	74.07	88.89	111.11	133.33	148.15	155.56	177.78	200.00
22	24.44	48.89	61.11	73.33	81.48	97.78	122.22	146.67	162.97	171.11	195.56	220.00
24	26.67	53.33	66.67	80.00	88.89	106.67	133.33	160.00	177.78	186.67	213.33	240.00
26	28.89	57.78	72.22	86.67	96.29	115.56	144.44	173.33	192.60	202.22	231.11	260.00
28	31.11	62.22	77.78	93.33	103.70	124.44	155.56	186.67	207.41	217.78	248.89	280.00
30	33.33	66.67	83.33	100.00	111.11	133.33	166.67	200.00	222.22	233.33	266.67	300.00
32	35.56	71.11	88.89	106.67	118.51	142.22	177.78	213.33	237.04	248.89	284.44	320.00
34	37.78	75.56	94.44	113.33	125.92	151.11	188.89	226.67	251.86	264.44	302.22	340.00
36	40.00	80.00	100.00	120.00	133.33	160.00	200.00	240.00	266.67	280.00	320.00	360.00
38	41.11	84.44	105.56	126.67	140.73	168.89	211.11	253.33	281.49	295.56	337.78	380.00
40	43.33	88.89	111.11	133.33	148.14	177.78	222.22	266.67	296.30	311.11	355.56	400.00
42	45.56	93.33	116.67	140.00	155.55	186.67	233.33	280.00	311.11	326.67	373.33	420.00
44	48.89	97.77	122.22	146.67	162.96	195.56	244.44	293.33	325.92	342.22	391.11	440.00

Gallons per 100′ of Road for Different Widths and Rates of Application — *continued*

Width in Feet	Number of Gallons to the Square Yard											
	1.0	1.1	1.2	1.25	1.3	1.33⅓	1.4	1.5	1.6	1.66⅔	1.7	1.8
8	88.89	97.78	106.67	111.11	115.56	118.52	124.44	133.33	142.22	148.15	151.11	160.00
10	111.11	122.22	133.33	138.89	144.44	148.15	155.56	166.67	177.78	185.19	188.89	200.00
12	133.33	146.67	160.00	166.67	173.33	177.78	186.67	200.00	213.33	222.22	226.67	240.00
14	155.56	171.11	186.67	194.44	202.22	207.41	217.78	233.33	248.89	259.26	264.44	280.00
15	166.67	183.33	200.00	208.33	216.67	222.22	233.33	250.00	266.67	277.77	283.33	300.00
16	177.78	195.56	213.33	222.22	231.11	237.04	248.89	266.67	284.44	296.30	302.22	320.00
18	200.00	220.00	240.00	250.00	260.00	266.67	280.00	300.00	320.00	333.33	340.00	360.00
20	222.22	244.44	266.67	277.78	288.89	296.30	311.11	333.33	355.56	370.37	377.78	400.00
22	244.44	268.89	293.33	305.56	317.78	325.93	342.22	366.67	391.11	407.41	415.56	440.00
24	266.67	293.33	320.00	333.33	346.67	355.56	373.33	400.00	426.67	444.44	453.33	480.00
26	288.89	317.78	346.67	361.11	375.56	385.19	404.44	433.33	462.22	481.48	491.11	520.00
28	311.11	342.22	373.33	388.81	404.44	414.82	435.56	466.67	497.78	581.51	528.89	560.00
30	333.33	366.67	400.00	416.67	433.33	444.44	466.67	500.00	533.33	555.55	566.67	600.00
32	355.56	391.11	426.67	444.44	462.22	474.08	497.78	533.33	568.89	592.58	604.44	640.00
34	377.78	415.56	453.33	472.22	491.11	503.71	528.89	566.67	604.44	629.62	642.22	680.00
36	400.00	440.00	480.00	500.00	520.00	533.33	560.00	600.00	640.00	666.67	680.00	720.0c
38	422.22	464.44	506.67	527.78	548.89	562.97	591.11	633.33	675.56	703.70	717.78	760.00
40	444.44	488.89	533.33	555.56	577.78	592.60	622.22	666.67	711.11	740.73	755.56	800.00
42	466.67	513.33	560.00	583.33	606.67	622.22	653.33	700.00	746.67	777.78	793.33	840.00
44	488.89	537.78	586.67	611.11	635.56	651.85	684.44	733.33	782.22	814.81	831.11	880.00

CHAPTER X

COST DATA AND ESTIMATES[1]

New methods of construction have so changed the cost of road improvements that engineers just going into this work, or those not familiar with present methods, are often handicapped in making estimates.

The cost data given in this chapter has been gathered chiefly since 1907 and covers most of the items necessary for estimating the cost of any ordinary road improvement. Such data must be used intelligently or it will be misleading. Local conditions should always govern in making estimates, and in presenting costs it is best to describe the conditions under which the work was performed, leaving their special application to the one using the data. An engineer's estimate should represent the probable average bid price. In the following examples of actual cost those have been selected that are considered to be average cases. Contractors who have an unusually good plant and a well-organized force can often do the work cheaper than is shown; on the other hand, those new to the work will spend more.

Where machinery is used it is more satisfactory to include the items of depreciation, repairs, and interest in a lump-sum item for the whole contract than to try to reduce it to a yardage basis. These charges will be considered under the heading of "Plant and Pay Roll."

BITUMINOUS AND WATERBOUND MADACAM CONSTRUCTION

Cost of Earth Excavation.

Table 43 shows the cost of earthwork on four roads in New York State, which represent easy, average, and difficult work. The cost per cubic yard includes excavation and placing in fill, shaping the subgrade for the stone, and trimming the shoulders and ditches. For heavy fills with short hauls wheeled scrapers were used, but the largest part of the work was done by wagons.

Cost of Rock Excavation.

The writer has no reliable personal data on ledge rock excavation. Rockwork on roads is usually a small item; the cuts are small and consequently expensive. Perhaps there is no item more variable in cost than small rock cutting. It is therefore safer to take as a basis of estimate the bids of experienced road

[1] Much of the data in this chapter was contributed by the author to the *Engineering News* and published July 13, 1911.

TABLE 43. EARTH EXCAVATION

Road No.	Length, Miles	Total Excavation Cu. Yds.	Wages per Hour		Cost per Cu. Yd.	Kind of Soil	Engineer
			Men	Teams			
1[1]	2.5	8,600	$0.175	$0.45	$0.452	Loam and gravel, easy work	E. E. Kidder
2	5.5	28,000	0.175	0.45	0.484	Largely clay, hard excavation	S. O. Steere
3	6.0	18,000	0.15	0.45	0.46	Gravel, sand, clay, loam, etc., average work	W. G. Harger
4[1]	4.0	10,000	0.175	0.40	0.65	25% of excavation, small boulders, unusually hard excavation	W. G. Harger

[1] The cost of trimming the shoulders on road No. 1 was $345.00 per mile; on road No. 4, $700.00 per mile.

contractors. The reports of the Massachusetts Highway Commission and bids on New York State work show that prices for rock excavation range from $1.50 to $2 per cubic yard, for quantities up to 200 or 300 cu. yds., and $1.25 to $1.50 for larger quantities.

Cost of Unloading Broken Stone.

For making estimates of the quantity of stone required the following data on imported limestone used on Road 5,021 will be useful. The approximate sizes and actual weights of stone on this work were as follows:

No. 1 Screenings, $\frac{5}{8}$ inch screen	2,550 lbs. per cu. yd.
No. 1A Dustless screenings, $\frac{5}{8}$ in. screen with dust jacket................	2,350 " " " "
No. 2, 1 in. screen	2,470 " " " "
No. 3, 2 " "	2,350 " " " "
No. 4, $3\frac{1}{2}$ " "	2,420 " " " "

For purposes of estimating the cost of handling imported crushed stone, the following weights for a cubic yard, based on railroad weights, will be used: No. 1, 2,600 lbs.; No. 1A, 2,400 lbs.; No. 2, 2,500 lbs.; No. 3, 2,400 lbs.; No. 4, 2,400 lbs.

Unloading Cars by Hand.

On Road 5,021, with the author as engineer, a number of short time (10-hr.) estimates made the cost of unloading per ton $0.12 to $0.135; and the cost per cubic yard $0.14 to $0.16. This work was in 1910, and labor cost $0.175 per hour. The shoveling was done from a steel platform, where it was dumped from hopper-bottom cars. When shoveled from inside the cars the cost may run as high as $0.20 per cu. yd. The cost of shoveling is usually estimated at $0.15 per cu. yd.

The time of loading $1\frac{1}{2}$ cu. yd. wagons by hand shoveling will range from 8 to 12 minutes.

Unloading Cars with Continuous Bucket Conveyor Elevator Plant.

Where there is a large quantity of stone to be unloaded and it is not possible to install an elevator plant on the existing track, it often pays to put in a switch. Six cars switches can be usually built for about $300.00. Where there are competing railroads no charge is usually made.

The following data is from Road No. 5,046, season of 1910, with labor at $0.175 per hour. The plant consisted of an ordinary continuous bucket conveyor operated by a 6 H.P. gasoline engine; the bin had a capacity of 100 tons.

The average fuel consumption was five gallons of gasoline per day. Cost of fuel and oil averaged $1.00 per day.

The average force at the elevator was one foreman and three helpers.

A total of 4,670 tons, or 3,890 cu. yds., was unloaded at $0.084 per ton, or $0.101 per cu. yd.

The cost was divided as follows:

Setting up elevator at Scottsville	$ 60.00
" " " " Mumford	40.00
" " " " Wheatland	75.00
Labor of operation	194.00
Gasoline and oil	25.00
Total	$394.00

This method of unloading is not only cheaper than hand methods but also cheapens the cost of hauling, as no time is lost in loading the wagons. The time of loading a $1\frac{1}{2}$ cu. yd. wagon from bins ranges from 45 to 55 seconds. There is also a saving in car demurrage if the bin holds two or three car-loads.

Elevator unloading saves about $0.04 per cu. yd. on team time and about $0.05 on the unloading, making a total saving per cubic yard of about $0.09. It usually costs about $150 to ship the plant and install it the first time, so elevator unloading is not adopted unless there are, at least, 2,000 cu. yds. of stone handled.

Unloading Cars from Coal Trestle.

This data is taken from the Scottsville road repair work, Mr. Harold Spelman, Engineer, season of 1910; labor at $0.20 per hour; average force, two or three men. A total of 4,400 tons was unloaded. The cost divided as follows:

Rent of trestle	$125.00
Labor	232.00
Total	$357.00
Cost per ton	0.081
" " cu. yd.	0.098

Unloading from Canal Boats.

The plant used consisted of a portable bin and a horse-operated derrick; Road 5,014; Mr. James Anderson, contractor. The average amount of stone unloaded per day was 150 tons. The cost was $0.115 per ton, or $0.14 per cubic yard, divided as follows:

1 team and driver	$ 4.00	(10-hour day)
1 foreman	2.50	" " "
6 laborers, at $1.75 per day	10.50	" " "
Total	$17.00	" " "

Cost of Hauling Broken Stone.

Table 44 shows the cost of hauling stone on good roads as for repair work. The wagons were loaded from bins, so no time was lost in loading.

TABLE 44.—HAUL OF STONE ON GOOD ROADS FOR REPAIR WORK

Road No.	Engineer in Charge	Price per Hour of Teams	Length of Haul, Miles	Cost per Ton, Mile	Cost per Yard, Mile
1	Harold Spelman . . .	$0.50	1.8	$0.20	$0.24
1	Harold Spelman . . .	0.50	1.2	0.24	0.288
2	G. G. Miller	0.62	2.0	0.20	0.24
2	G. G. Miller	0.62	1.7	0.215	0.26
2	G. G. Miller	0.62	1.1	0.23	0.275
2	G. G. Miller	0.62	0.6	0.25	0.30
2	G. G. Miller	0.62	0.2	0.50	0.60
3	G. G. Miller	0.62	3.0	0.17	0.205
3	G. G. Miller	0.62	2.75	0.175	0.21
3	G. G. Miller	0.62	2.5	0.175	0.21
3	G. G. Miller	0.62	2.0	0.19	0.23
3	G. G. Miller	0.62	1.75	0.215	0.26
3	G. G. Miller	0.62	1.5	0.23	0.28

Road No. 1, 10-hour day.
Roads No. 2 and 3, 8 hours per day.

NOTE.—Cost per ton mile on Roads No. 2 and 3 equals the cost per yard mile, for teams at $0.50 per hour.

For hauling on bad roads for new construction I have the following personal data:

Clover Street Road, Section 1, season 1908; teams at $0.45 per hour; dump wagons loaded from bins; no time lost.

6,000 cu. yds., 0.6 mile haul cost 26 cts. per ton, or 31 cts. per yard mile.

4,500 cu. yds., 0.6 mile haul, cost 24 cts. per ton, or 29 cts. per cubic yard mile.

Scottsville-Mumford Road, season of 1911; teams, $0.45 per hour. 300 cu. yds., 1 mile haul (including a 5 per cent sandy hill 1,200 ft. long) cost $0.30 per yard mile.

500 cu. yds., 0.5-mile haul (level road in bad condition) cost $0.30 per yard mile.

Hauling Field Stone and Filler. This material was hauled from fields and pits where it was loaded by hand, and considerable time thus lost.

On the Clover Street Road, Section 1, season of 1908, with the author as Engineer, and teams at $0.45 per hour, 10,000 cu. yds. of field stone were hauled an average of one mile for $0.36 per yard mile.

On the Scottsville-Mumford Road, season of 1911, with the author as Engineer, and teams at $0.45 per hour, 500 yds. of field stone were hauled 0.2 mile at $0.14 per cu. yd., or $0.70 per yard mile. On the same work 200 cu. yds. of filler was hauled 0.2 mile for $0.15 per cu. yd., or $0.75 per yard mile.

For all short hauls under $\frac{1}{4}$ mile the cost is high and practically the same on account of the larger percentage of time lost in loading.

Mechanical Hauling. This method has not come sufficiently into general use to be considered in estimating, in the writer's opinion, unless it is difficult to get teams. It rarely pays to use traction engines for less than a three-mile haul, even on a hard road. In case they are used a light engine or road-roller and a train of ordinary dump wagons are more satisfactory than a heavy engine and large 5 or 7 cu. yd. cars. For maintenance and repair work, however, some style of automobile truck will, doubtless, be used in the near future. Under favorable circumstances mechanical hauling will cost about 12 to 15 cents per yard mile.

Cost of Loading Local Fence Stone into Wagons.

Road No. 5,046, W. G. Harger, Engineer, season of 1911, Labor $0.175 per hour.
2,200 cu. yds., boulders loaded at a cost of $0.14 per cu. yd.

A gang of six men will take from 9 to 13 minutes in loading $1\frac{1}{2}$ cu. yds., depending upon the size of the stone.

Road No. 495, E. E. Kidder, Engineer, season of 1911, Labor, $0.175 per hour.
1080 cu. yds., boulders loaded at a cost of $0.184 per cu. yd.

Road No. 492, E. E. Kidder, Engineer, season of 1911, Labor $0.175 per hour, 300 cu. yds., loaded at $0.137 per cu. yd.

COST OF SPREADING STONE AND BINDER

Table 45, page 272, gives the cost of spreading broken stone on several New York State roads.

The ratio of the loose to the rolled depths varies with the size of the fragments and the depth of the course. Table 46, page 272, gives the averages of the results obtained from 1,000 test holes made by the writer on three separate roads. The last column of the table also gives the weights of No. 3 and No. 4 stone required to make a cubic yard of rolled macadam. The amount of filler or binder per cubic yard of rolled macadam is given in Table 47, page 272.

The excessive amount of filler required for the 2-inch bituminous macadam, Table 47, was due to a layer of screenings placed under the No. 3 stone, all of which did not act as a filler. The small amount required for the 3-inch bituminous macadam was due to the fact that the bituminous binder partially filled the voids before the screenings were applied.

The ratio of loose to rolled depth for boulder sub-base is variable.

If the size of boulders is practically the same as the depth of the course, that is, if there is only one layer of stone, the loose depth and the rolled depth will be the same. Where there are

two or three layers of boulders the ratio is, approximately, 1:1.25, i. e., a 12-inch, rolled depth would require 15-inch loose depth for boulder averaging 5 to 6 inches in diameter.

TABLE 45.—SPREADING STONE

Reference No.	Engineer	Labor Wage	Depth of Loose Spread	Amount Spread	Cost per Ton	Cost per Cu. Yd.
1	Harold Spelman ..	$0.20	4 in.	7000 tons	$0.066	$0.08
2	W. G. Harger	0.175	$5\frac{1}{3}$ in.	6000 cu. yds.	0.05	0.06
2	W. G. Harger	0.175	4 in.	4500 " "	0.07	0.083
3	W. G. Harger	0.20	6 "	1000 " "	—	0.05
		Placing sub-base stone				
3	W. G. Harger	0.175	7 in.	100 " "	—	0.10
3	W. G. Harger	0.175	10 " gravel	200 " "	—	0.04
4	E. E. Kidder......	0.175	6 "	267 " "	—	0.07
[1]5	E. E. Kidder.. ...	0.175	6 "	1082 " "	—	0.12

TABLE 46.—RATIO OF LOOSE TO ROLLED DEPTH

Size of Stone	Rolled Depth	Loose Depth	Ratio	Weight per Cubic Yard Rolled Measure[2]
No. 4	4 in.	5.2 in.	1.3	3120 lbs.
No. 4	3 "	3.8 "	1.27	3050 "
No. 3	3 "	3.9 "	1.3	3120 "
No. 3	2 "	2.4 "	1.2	2880 "

TABLE 47.—AMOUNT OF FILLER AND BINDER REQUIRED

Kind of Course	Kind of Filler	Amount of Filler per Cu. Yd. of Rolled Macadam	Weight of Screenings per Cu. Yd. of Rolled Macadam
Bottom stone	Sand	0.35 cu. yds.	—
Waterbound top[3]...	No. 1	0.50 " "	1300 lbs.
3-in. Bit. mac. top[3].	Nos. 1A and 2	0.37 " "	900 "
2-in. Bit. mac. top[3].	No. 1A	0.60 " "	1440 "
Sub-base	Gravel	0.33 " "	—

[1] Sub-base bottom course. The cost includes sledging of all large stone.
[2] Weight of cubic yard loose 2,400 lbs., as noted at the beginning of the chapter.
[3] Weight of cubic yard loose 2,400 lbs. Filler for top course includes wearing coat.

Cost of Loading Filler at Pit. On the Clover Street Road, Section 1, during the season of 1908, with the author as engineer and labor at $0.15 per hour, 400 cu. yds. of sand filler were loaded at a cost of $0.12 per cu. yd. On the Scottsville-Mumford Road, with labor $0.175 per hour, 200 cu. yds. were loaded at a cost of $0.13 per cu. yd.

Cost of Spreading Filler by Hand from Piles Spaced 20′ to 30′ Apart. On the Clover Street Road, Section 1, during the season of 1908, with labor at $0.15 per hour, 400 cu. yds. of sand filler were spread at a cost of $0.10 per cu. yd. On the Scottsville-Mumford Road, with labor at $0.175 per hour, the cost of spreading 200 cu. yds. was $0.20 per cu. yd. This includes some hand brooming, but most of the brooming was done by a broom attachment on the roller.

Cost of Spreading No. 1A and No. 2 Stone for Bituminous Macadam Top Courses and Brooming Same. A layer of No. 1A, $\frac{1}{2}$ inch deep, was spread over the bottom course. On this was spread $2\frac{1}{2}$ inches of No. 3 stone. After rolling bitumen was poured over this course and a $\frac{3}{4}$-inch layer of No. 2 stone spread and rolled; the excess of No. 2 was broomed off and a $\frac{3}{8}$-inch wearing coat of No. 1A placed.

The cost of spreading for a 2-in. top was as follows:

Cost of No. 1A and No. 2 per cu. yd.	$0.282
Cost per ton of No. 1A and No. 2	0.210

Eight hundred tons of this material were handled with labor costing $0.175 per hour.

For a 3-in. top course the procedure was the same, omitting the layer of No. 1A under the No. 3 stone. The cost of handling 400 tons for the 3-in. course was as follows:

Cost per cu. yd of No. 1A and No. 2 ...	$0.31
Cost per ton of No. 1A and No. 2	0.26

Cost of Spreading Screenings with Cross Dump Wagons. Wet dust screenings for waterbound macadam cannot be successfully spread in this manner. For spreading dry dust screenings, No. 2 stone or dustless screenings for bituminous macadam, this method has proved the cheapest and most satisfactory. On Road 5,046, season of 1910, a number of short-time estimates made the cost of spreading by this method about $0.06 per cu. yd. The cost of brooming is slightly increased over that required by the hand-spreading method, but not enough to counteract the advantage in the use of the wagon spreading. On the Clover Street Road, season of 1908, 1,000 cu. yds. of screenings were thus spread for about $0.07 per cu. yd.

COST OF ROLLING

In the following costs lubricating oil is not included, as no reliable data was obtained as to the quantity used. Gillette's "Handbook of Cost Data" gives this item as $0.30 per day; using this amount would increase the costs given below from 0.2 to 0.3 of a cent per cu. yd. The amount of coal used was variously

estimated at from 450 to 500 lbs. per day. As before mentioned, items of depreciation, repairs of plant and equipment, and interest are not included in the cost per cubic yard of stone consolidated.

On Road 5,025, under Mr. E. E. Kidder, Engineer, during the season of 1910, the cost of rolling 3,400 cu. yds. of bottom stone and 1,700 cu. yds. of top stone, loose measure, was as follows:

Rollerman, 4 months, at $90	$360.00
Coal, $\frac{1}{4}$ ton per day, at $2.70 per ton, 80 days	55.00
	$415.00

The time and cost were divided as follows:

$\frac{1}{6}$ on subgrade	$ 69.00
$\frac{1}{3}$ on bottom stone 4″ deep	138.00
$\frac{1}{2}$ on bituminous top stone, 2″ deep	208.00

There was no cost for water. The roller worked 80 days in 4 months. The cost of rolling per cubic yard of loose material was: bottom stone, $0.04, and top (bituminous macadam) $0.12.

On Road 492, Mr. E. E. Kidder, Engineer, season of 1910, the cost of rolling 3700 cu. yds. of 4-in. bottom course was $0.03 per cu. yd., and for 3,200 cu. yds. of waterbound top stone $0.05 per cu. yd. Both quantities refer to loose measure. The roller worked 74 days in three months. The puddling was done by a pipe line and hose and brooms attached to the roller. The rollerman's wages were $90.00 per month and coal $2.75 per ton.

On Road 5,021 the cost of rolling a 3-in. bituminous top course per cubic yard of loose material was $0.09; for a 2-in. top $0.11.

On Road 5,046 a roller working 111 days consolidated 1,850 cu. yds. of field stone sub-base, 4,300 cu. yds. of bottom stone, and 2,150 cu. yds. of top stone, loose measure. The depth of the sub-base was 6 in. (rolled measure), the bottom course 4 in., and the top course $2\frac{1}{2}$ in., bituminous macadam. The rollerman's wages were $90 per month and coal cost $2.75 per ton for $\frac{1}{4}$ ton per day. There was no cost for water. The costs were divided as follows: sub-base, $0.035; bottom stone, $0.045; top stone, $0.105 per cu. yd., loose measure.

COST OF CRUSHING STONE

As a basis for all cost estimates for crushing, it is necessary to know something of the percentage of the different sizes of the crusher output. Table 48, page 275, gives the results of tests made by Mr. Archer White during the season of 1910 on ordinary limestone and sandstone boulders composing the average field stone. The crusher used was the largest Acme portable crusher. The tailings were recrushed and the stone divided into four grades: No. 1, $\frac{3}{4}$-in. screen; No. 2, $1\frac{1}{2}$-in.; No. 3, $2\frac{1}{2}$-in., and No. 4, $3\frac{1}{2}$-in. From this data it may be seen that 1 cu. yd. of field stone makes 1 cu. yd. of crushed stone, and that it takes approximately 1.8 cu. yds. of field stone to make 1 cu. yd. rolled measure of sizes Nos. 3 and 4. The crusher toggle was set to produce both top and bottom stone sizes.

TABLE 48.—SIZES AND PROPORTIONS OF CRUSHER RUN

Reference No.	Cu. Yds. Field Stone Delivered to Crusher	Cu. Yds. Crushed Stone Produced	Number 1		Number 2		Number 3		Number 4		Kind of Material
			Cu. Yds. Produced	% of Total Output	Cu. Yds. Produced	% of Total Output	Cu. Yds. Produced	% of Total Output	Cu. Yds. Produced	% of Total Output	
1	195	190	36	19	18	9	64	34	72	38	Sandstone and limestone
2	187	182	32	17½	10	5½	70	38½	70	38½	Limestone
3	196	202	36	18	14	7	76	38	76	37	Limestone and sandstone
4	190	216	40	18	18	8	79	37	79	37	Sandstone
5	173	172	32	19	28	16	62	36	50	29	Poor sandstone
6	189	184	36	19½	16	9	*	—	132	71½	Limestone
7	165	170	32	19	22	13	*	—	116	68	"
8	—	—	30	16	24	13	*	—	60	63	Soft sandstone

* No. 3 and No. 4 size mixed and placed on grade.

The cost of labor was $0.20 per hour. The engineman of the crusher plant received $0.25 per hour and the foreman $0.30 per hour. The field stone was loaded from a pile near the crusher into small dump cars running on a movable track. The loaded cars were drawn to the crusher by a small hoisting engine. The cost of bringing the field stone to the crusher pile is not included. The force loading consisted of one foreman, eleven laborers, and one engineman. The force crushing consisted of one foreman, four laborers, and one engineman. In eight days 1,500 cu. yds. were crushed. The cost of the entire output per cubic yard of loose measure was divided as follows:

Loading stone for crusher	$0.133
Hauling to crusher	0.013
Feeding to crusher	0.061
Engineer to crusher	0.013
Fuel and oil	0.030
Loading crushed stone from bins	0.010
Total	$0.260

Crushing Granite Hardheads and Sandstone. The following data is from the records of the Clover Street Road, Section 1, season of 1908. Labor cost $0.15 per hour and the engineman received $3 per day. The crusher used was a 10″ × 20″ Climax. A total of 5,000 cu. yds. of granite were crushed at a cost per cubic yard, loose measure, of $0.19; 7,000 cu. yds. of sandstone boulders were crushed at a cost of $0.103 per cu. yd., loose measure. These figures are for the total output of the crusher and include the costs of feeding to the crusher, the pay of the engineman, coal, oil, but not the delivery to the crusher. On the Scottsville-Mumford Road under similar conditions the cost varied from $0.13 for granite and sandstone to $0.19 for granite hardheads per cubic yard of loose measure.

Crusher force on the Clover Street and Scottsville-Mumford roads as follows:

1 foreman	$4.00
5 men feeding crusher	2.00 each
1 man tending screen	2.00
1 engineer	3.00
Fuel and oil	4.00

Where bottom stone alone is being crushed from local material the crusher is set to produce a larger amount of No. 4 stone, and the proportion of the screenings to the No. 3. and No. 4 size is different than given in Table 48.

In the following data from Road 5,046, Scottsville-Mumford, mentioned above, the No. 3 and No. 4 and tailings were used as the bottom course stone, the tailings being broken into proper sizes after the stone was spread by knapping hammers. The cost of knapping will vary from $0.01 to $0.03 per cu. yd. of

loose bottom stone, depending on the number of tailings produced. When the crusher is set correctly to deliver a good grade of stone for bottom course, this charge should not amount to over \$0.01 per cu. yd. of total output and is properly chargeable against crushing, which increases the crushing costs given above from \$0.13 to \$0.14 and from \$0.19 to \$0.20.

The size of screens were $\frac{5}{8}''$, $1\frac{1}{4}''$, $2\frac{1}{2}''$, and $3\frac{1}{2}''$.

Crusher Set-up, No. 1. 60% Granite, 30% sandstone, 10% soft rock.

Total screenings, No. 1	240 cu. yds.
" No. 2	no record
" No. 3, 4, and tailings	1,500 cu. yds.

Crusher Set-up, No. 2. 50% granite, 40% sandstone, 10% soft rock.

Total screenings	350 cu. yds.
" No. 2	no record
" No. 3, 4, and tailings	2,600 cu. yds.

For this same road the amount of field stone required per loose yard of bottom stone is shown by the following figures. Approximately 1.5 yard loads were drawn to and from crusher.

Date	Number Loads of Field Stone Crushed	Number Loads of No. 3 and No. 4 and Tailings Drawn from the Crusher
1911		
April 24	114	93
" 25	86	70
" 26	87	69
May 5	104	84
" 6	101	82
" 8	106	85
" 9	99	78
" 10	86	72
" 11	107	95
" 12	110	80
" 13	102	83
Totals	1102 loads 1653 cu.yds.	891 loads 1336 cu. yds.

On this work 1.24 cu. yds. field stone produced 1 cu. yd. loose measure bottom stone, and 1.61 cu. yds. field stone produced 1 cu. yd. bottom stone rolled measure.

Table 48, page 275, gives 1.8 cu. yds. field stone to 1 cu. yd. rolled macadam, but this apparent difference is explained by the fact that the tailings were recrushed and the crusher set closer to produce top as well as bottom stone, consequently the per cent of No. 1 and No. 2 is higher than for the data just given.

Data obtained by Mr. Frank Bristow, First Assistant Engineer, New York State Department of Highways, indicates that 1 cu. yd. of field stone produces 1.1 cu. yds. crushed stone when separated by screens of $\frac{1}{2}''$, $1\frac{1}{4}''$, $2\frac{1}{2}''$, and $3\frac{1}{2}''$; this is slightly more than the writer's experience has indicated.

When local stone is crushed for bottom only, the screenings are used as filler for that course, and in a case of this kind it is necessary to know how much additional filler must be estimated. Take the case of the Scottsville-Mumford Road (crusher set-up No. 2) given above. Twenty-six hundred cubic yards loose measure will consolidate under the roller to approximately 2,000 cu. yds. of rolled bottom stone. This will require 2,000 × 0.35 = 700 cu. yds. filler. The amount of screenings produced in crushing 2,600 cu. yds. of bottom was 350 cu. yds., showing that for cases similar to the one given, half of the total filler required must be obtained from other sources.

Cost of Sledging Boulders. A certain percentage of the fence stone must be broken to reduce them to a proper size for crushing. This is done by blasting or sledging; where the boulders need to be broken only two or three times to reduce it to a usable size, sledging is the cheaper method. The cost of both of these methods is so variable that any cases cited would not be of much value. As given on page 260, under Standard Estimates, the author allows arbitrarily $0.40 per cu. yd. for all boulders actually sledged or blasted, and in making estimates the per cent to be treated in this manner is approximated roughly.

As a matter of interest Gillette, in his cost data on rockwork, gives the cost of sledging small sandstone boulders as approximately 0.05 per cu. yd., and the cost of mud capping at about 0.35 per cu. yd.

COST OF CRUSHING (continued)

The following data is taken from the Report of the Massachusetts Highway Commission and refers to work done in Newton, Mass. The crushed stone was divided into the following sizes:

Tailings	205 cu. yds.	....17.5%
$2\frac{1}{2}''$ stone	692 cu. yds.	....57 %
Screenings and 1'' ..	300 cu. yds.	....25.5%
Totals..........	1197	100 %

The material was cobblestones and labor probably cost $0.20 per hour, teams, $0.45. The cost per cubic yard at the crusher was $0.445, or $0.33 per ton.

The cost per cubic yard was divided as follows:

Teaming to crusher	$0.314	70.6%
Feeding to crusher	0.033	7.4%
Engineer of crusher	0.029	6.5%
Repairs, coal, oil, etc.	0.045	10.1%
Watchman	0.024	5.4%
Total	$0.445	100%

Material. Conglomerate.

Amount broken .... 1,288 cu. yds.
Amount broken per hour ...... 8.9 " "

Divided as follows:

		Weight per cu. yd. loose
Tailings, 378 cu. yds.	29.3%	2,549 lbs.
$2\frac{1}{2}''$ stone, 668 cu. yds.	51.9%	2,368 "
Screenings and 1″, 242 cu. yds.	18.8%	2,727 "

Cost per cu. yd. in bins at crusher $1.112
Cost of per ton in bins at crusher 0.885

Divided as follows:

	Cost	Per Cent
Powder and repairs	$0.018	1.6
Labor drilling	.249	22.3
Sharpening drills and tools	.023	2.1
Breaking stone for crusher	.420	37.8
Loading stone for crusher	.127	11.4
Hauling stone for crusher	.062	5.6
Feeding crusher	.053	4.7
Engineer for crusher	.038	3.5
Coal, oil, and waste	.050	4.5
Moving and setting crusher	.023	2.1
Watchman	.049	4.4
Total	$1.112	100

Material. Greenish trap.

Amount broken .... 3,155 cu. yds.
Amount broken per hour .... 7.7 " "

Divided as follows:

		Weight per cu. yd. loose
Tailings, 1,004 cu. yds.	31.8%	2,457 lbs.
$2\frac{1}{2}''$ stone, 1,618 cu. yds.	51.3%	2,383 "
1″ stone, 323 cu. yds.	10.2%	2,277 "
Screenings, 210 cu. yds.	6.7%	2,585 "

Cost per cu. yd. in bins at crusher $0.898
Cost per ton in bins at crusher 0.745

Divided as follows:

	Cost	Per Cent
Labor, steam, drilling	$0.092	10.3
Coal, oil, waste, powder, etc.	0.084	9.4
Sharpening drills and tools	0.069	7.7

Breaking stone for crusher	0.279	31.0
Loading stone for crusher	0.098	11.0
Hauling stone for crusher	0.072	8.0
Feeding crusher	0.053	5.9
Engineer of crusher	0.031	3.4
Coal, oil, waste, and repairs of crusher	0.079	8.8
Other repairs	0.041	4.5
Total	$0.898	100

W. E. McClintock, Engineer, Chelsea, Mass., season 1887:

Labor	$0.20 per hour
Teams	0.45 " "

Material. Trap rock.

Amount broken .... 1,718 tons

Stone delivered at crusher by subcontractor for $0.75 per ton.

Cost.	Tools	$0.013
	Oil, waste, etc.	0.016
	Fuel	0.050
	Stone at crusher	0.750
	Crushing (labor)	0.194
	Total per ton	$1.023

Dustless Screenings. The construction of bituminous macadams requires a dustless screening product referred o in the beginning of the chapter as No. 1A; it is obtained by rescreening the ordinary screenings (¾″ product) to remove the dust; the percentage of dust in the ordinary screenings will vary according to the stone crushed and the setting of the crusher jaws. The author has no reliable data for small crushing plants, but through the courtesy of the Buffalo Cement Company the following data is given for their output of limestone screenings at Buffalo, N.Y.

Size of screen opening for ordinary screenings	¾″
Size of dust screen openings	⅛″

Cu. yds. of dust for 1 cu. yd. ordinary screenings	0.35
" " " dustless screening 1 cu. yd. ordinary screening	0.65

The same data from the Leroy plant of the General Crushed Stone Company gives:

Size of screen openings for ordinary screenings	⅝″ to $\frac{11}{16}$″
" " dust screen openings	¼″ " $\frac{5}{16}$″
Cu. yd. of dust per cu. yd. ordinary screenings	33%
" " " Dustless screenings per cu. yd. ordinary screenings	67%

Percentage of screenings to total output for Leroy limestone approximates 15%.

The above furnished to the writer through the courtesy of the General Crushed Stone Company, of Easton, Pa.

COST OF STONE FILL BOTTOM COURSE

The following data is taken from Road 5,021, season of 1910; labor cost $0.175 per hour, teams $0.40 per hour.

The amount placed was 10,000 cu. yds. rolled measure. The average rolled depth was 1.1 ft. The surface was carefully brought to line and grade, allowing a variation of 1 in. either above or below, which inequality was taken out with the top stone. A 3 in. bituminous top course was placed directly on this fill. The top layer of bottom stone was sledged to reduce all stones to 8 in. or under. Flint stone was used to fill the top 6 in. and to surface the rough fill. The bottom course was of fence stone, hauled, on an average, about one-half mile. I estimate that one cubic yard rolled measure requires 1.25 cu. yds. loose. The cost of the bottom course per cubic yards rolled measure was $1.03, divided as follows:

Loading 1.25 cu. yds.	$0.19
Hauling 1.25 " " ½ mile	0.20
Placing 1.25 " " and rolling	0.24
Sledging	0.15
Flint	0.10
Cost of fence stone	0.15
Total, per cu. yd.	$1.03

Cost of Sub-base Bottom Course. Road 495, Parma Corners-Spencerport. E. E. Kidder, Engineer. 1,082 cu. yds. placed, average depth 6″. Not much sledging required.

Cost of stone, 1 cu. yd.	$0.10
Loading, per 1 " "	0.184
Hauling 1 mile	0.30
Laying, sledging and spreading filler	0.136
Rolling	0.02
Superintendence	0.02
Cost of filler in pit nothing (gravel used).	0.00
Loading ⅓ cu. yd.	0.04
Hauling ⅓ cu. yd. 1 mile	0.10
Total	0.90

COST OF APPLYING BITUMINOUS BINDER

The following data is taken from Road 5,021, season of 1910. Bituminous macadam, penetration method:

Labor.

Kettleman	$0.20 per hour
Spreaders	0.20 " "
Plain labor	0.175 " "
Teams	0.45 " "

Apparatus.

4 bbl. kettle (coal burner)	Bitumen heated
2 bbl. " (wood burner)	to 400° F.

12 ton Kelly roller . . . .
Spreading pots having a vertical slot 1/8" wide.

Organization.

Rollerman acting as foreman
1 Spreader
1 Kettleman
3 Laborers

Average speed 350 ft. of 16 ft. road, per day.

Quantities.

16,850 gals. laid in one coat covered 13,330 sq. yds., or 1.26 gals. per sq. yd.

Cost per gal.	Unloading and hauling 1/2 mile	$0.0015
	Heating	0.0032
	Spreading	0.0032
	Rolling and supervision	0.0051
	Total	$0.0130
Bituminous material f.o.b. Caledonia		0.0950
	Total per gal.	$0.1080

Second quantity.

Forty-two thousand gallons covered 24,000 sq. yds. in one coat, an average of 1.75 gals. per sq. yd.

Cost per gal.	Unloading and hauling 1 3/4 miles	$0.0032
	Heating	0.0040
	Spreading	0.0039
	Rolling and supervision	0.0042
	Total	$0.0153
Bituminous material f.o.b. Caledonia		0.0950
	Total per gal.	$0.1103

Cost of Applying Bituminous Binder. Road 5,046, *Penetration Method.*

18,890 gals. spread on 12,378 sq. yds. in one coat, of 1.52 gals. per sq. yd.

Apparatus.

5 2 bbl. kettles (wood burners) Fuel. Used bbl. staves and some extra wood.
1 10-ton Buffalo Pitts Roller.
Spreading hods.

Organization.	Per Hour
1 Foreman	$0.30
2 Pourers, each	0.25
5 Kettlemen, each	0.20
2 Spreaders of No. 2, each	0.20
4 Helpers, each	0.175

Labor of Placing. Cost per gallon.

Fuel	$0.001
Kettlemen	0.005
Pouring	0.003

Helpers	0.007
Supervision	0.002
Total	$0.018
Material f.o.b. Scottsville	0.093
Total per gal.	$0.111

Kentucky Rock Asphalt. I have the following data from the Clarence Center Road, Mr. John D. Rust, Engineer, collected during the season of 1910. In this work an 8-ton tandem roller was found to do better than a 6-ton tandem. The cost of handling, spreading, and rolling this material, from data of five days selected, varied from $0.033 to $0.036 per sq. yd.; the average being $0.034. The following may be taken as a typical analysis of this cost:

Abbreviations. L. Laborers.
F. Foreman.
T. Teams.
E. Roller engineer.

Asphalt $10.25 per ton f.o.b. unloading point.
Run of July 20, 1909.
69.22 tons hauled and placed.
1,730 sq. yds. covered.
80 lbs. asphalt per sq. yd.

5 L. at cars, 10 hours, at $1.50 each	$ 7.50
½ F. at cars at $2.25 per day	1.12
5 T. haul 2 miles at $4.00 per team	20.00
5 L. on wheelbarrows, 11 hours, each $0.15 per hour	8.25
1 T. at shredding machine	4.40
3 L. on rakes, 11 hours at $0.15 per hour	4.95
3 L. shoveling, 11 hours, at $0.15 per hour	4.95
1 F. at shredder, 11 hours at $0.225 per hour	2.48
1 E. on roller, 11 hours at $0.30 per hour	3.30
Total	$56.95

Cost per square yard, $0.033.

PUDDLING WATERBOUND ROADS

There are two methods of puddling:
First, by Pipe Line and Hose.
Second, by Sprinkling Carts.

In the first method a 1½-in. or 2-in. pipe line is laid along the road with taps every 200 to 300 feet. The road is wet down by a hose fastened to these taps and sprayed on by a nozzle, or the hose is fastened to a sprinkling attachment on the roller, which throws the water directly onto the wheels; this method is cheaper and more satisfactory than using sprinkling carts, but to work well a pressure of 125 lbs. should be maintained at the pump, which requires a better pumping apparatus than contractors usually have. A very satisfactory plant, used near Rochester, N.Y.,

consisted of a Gould Triplex Pump, operated by a 6-H.P. gasoline engine; the relief valve at the pump was set at 120 lbs.

The cost of such puddling on Road 492 for 3,000 cu. yds. of top course was $0.05 per cu. yd.; on Road 294 for 4,000 cu. yds. of top course it was $0.06. This cost includes pumping, helper tending hose, and rollerman. Brooms on the roller were used which materially reduced the cost of brooming the screenings. No charge for water, no allowance made for laying the pipe line; this last charge is included in the lump-sum item of installing plant for a waterbound road, page 311.

Gillette, in his handbook, gives sprinkling by carts approximately $0.10 per cu. yd. of top course, which includes sprinkling the subgrade as well as puddling the top course. As the subgrade is rarely sprinkled, his data reduced to the conditions cited on roads 492 and 294 would give approximately $0.06 per cu. yd. of top course. To this is added the cost of rolling, or about $0.04, which makes the cost of puddling by this method about $0.10 to $0.12, or about twice the amount of the first method.

Mr. E. A. Bonney, on the Hamburg-Buffalo road, from a metered supply of water, states the amount required to first puddle a 3-in. top course varies from 50 gals. to 55 gals. per cu. yd. of top course, and the amount needed for the second puddle will be considerably less.

Mr. H. P. Gillette states, in a monograph on the Economics of Road Construction, that 30 gals of water per cu. yd. will puddle a road. Mr. E. E. Kidder states that approximately 80 gals. are required per cu. yd. of top course for two puddles. The author's experience agrees with the larger quantities.

McClintock Cube Pavement. The general costs of this experimental pavement were given in chapter V. We here give the detailed cost of the vitrified clay cubes and clay-ash cubes only, as the concrete cubes have not worn satisfactorily.

Vitrified Shale Cubes. During 1909, 74,000 2½-in. vitrified shale cubes manufactured at Reynoldsville, Pa., were laid at a cost as follows:

Teams at $0.50 per hour.

74,000 cubes f.o.b. Reynoldsville	$231.25
Freight	68.41
Carting	67.00
Laying	20.00
Total	$386.66

NOTE. 331 sq. yds. were covered at a cost of $1.17 per sq. yd.

Clay and Ash Cubes. In 1910, cubes made of a local clay mixed with ashes and burned were tried in the effort to get a cheap, tough clay product. As far as known, this is the first time bricks made in this way have been used on roadwork.

The ash-clay process has been worked out and patented by Karl Langenbeck, of Boston, Mass. Many local clays used for ordinary brick or farm tile will not stand up under vitrification

without the addition of expensive, imported refractory clays; but the substitution of coal ashes for the more expensive clays has a similar effect and the cost is materially reduced. Some of the local clay was sent to Mr. Langenbeck, who turned out a few cubes that compare favorably in toughness with the best paving bricks on the market.

The Standard Sewer Pipe Company, of Rochester, N.Y., undertook to furnish 400,000 2-in cubes of this description for Mr. McClintock. It was necessary for them to experiment to determine a practical method of molding, the correct temperature to use, and the best proportion of ashes, which naturally raised the price above ordinary practice. In molding they used a modification of the ordinary pipe-molding machine, which produced a hollow square of cubes, at the rate of 30,000 cubes per hour. The scoring knives were so set that the cubes were nearly cut apart, leaving just enough uncut clay to hold them together during the burning, after which a light blow separated them cleanly. The toughness of the resulting cubes can probably be increased by further experiment; but the product was good, although not up to the standard of the sample cubes made by Mr. Langenbeck.

The cost of the ash-clay cubes was as follows:

400,000 cubes f.o.b. Rochester, N.Y.	$1,200.00	$0.711 per sq. yd.
Carting, six miles	247.75	0.147 " " "
Filler	27.00	0.016 " " "
Labor of laying	191.77	0.113 " " "
Roller	12.94	0.008 " " "
Total	$1,679.46	$0.995 " " "

NOTE. 1,688 sq. yds. covered
Labor, $0.22 an hour } for laying and carting.
Teams, $0.50 an hour }

Mr. McClintock has stated, in discussing the cost, that in large quantities he believes the cubes can be delivered f.o.b. at the plant for $1.50 per 1,000, which would reduce the cost as shown above to about $0.60 per sq. yd., and that the high cost of laying was due to the irregular shape of the first batch, due to not scoring the cubes deeply enough.

Amiesite Cost Data. Road 1319, Honeoye Village, Season of 1915. H. W. Baker, Eng. in charge. 4700 sq. yds. laid 16′ wide $2\frac{3}{4}''$ deep. Laid in two courses. Bottom course $2\frac{1}{4}''$ thick coarse material; surface $\frac{1}{2}''$ thick fine material.

Material	
588 tons @ $4.00 per ton f.o.b. plant	$2352.00
588 tons freight $0.54 per ton	341.04
Total cost materials	$2693.04

Labor	
Force at cars unloading	
6 Laborers @ \$2.00 per day	\$12.00
1 Foreman @ \$2.50 per day	2.50
1 Fireman @ \$3.00 per day	3.00
1 Night Fireman @ \$2.50 per day	2.50
	\$20.00
Equipment at Cars	
1 boiler and pipe line per day	8.00
½ ton coal and oil	2.50
Total daily cost of unloading	\$30.50
Hauling ¾ mile	
4 teams @ \$5.00 per day	\$20.00
Spreading and Compacting	
1 Asphalt raker	3.00
4 Laborers @ \$2.00 per day	8.00
1 Rollerman	3.00
per day	\$14.00
Equipment	
1 roller (10 ton tandem)	10.00
Coal, oil, etc.	0.80
Daily cost spreading and compacting	\$24.80
Summary Daily Force Account	
Unloading	30.50
Hauling	20.00
Spreading and compacting	24.80
	\$75.30
Number of days worked, 15	
Total labor 15 days	\$1129.50
" materials cost	2693.04
Total cost	\$3822.54
Cost per sq. yd.	0.81
Bid price sq. yd.	0.85

Conditions

This work was done under bad weather conditions the night temperature being below freezing and only two days with an air temperature above 55° F.

It was necessary to keep a night fireman at the cars to keep up steam and to move the steam pipes to different parts of the cars to insure the amiesite being in a condition to loosen and shovel in the morning. The material was loosened by bars and sledges to the bottom of the cars steamed 10 to 30 minutes and then shoveled into dump wagons, covered with canvas and hauled to the street.

Under favorable weather conditions the cost of unloading from the cars would probably be reduced 40%.

Table of Amounts of Amiesite required for different thicknesses and materials.

Amiesite. Table of Depths and Weights — (*Weights Given are per Square Yard*)

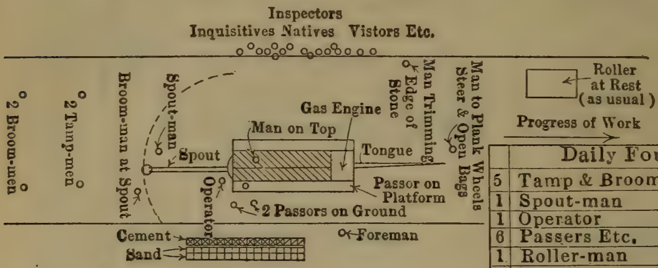
	Amiesite Loose	Weight Pounds	Amiesite Sq. Yds. Per Ton	Filler Loose	Weight Pounds	Filler Sq. Yds. per Ton	Total Depth Loose	Total Weight Pounds	Ultimate Compression	Square Yds. Per Ton
Limestone	$2\frac{1}{4}$″	153	13	1″	$67\frac{3}{4}$	29.5	$3\frac{1}{4}$″	$220\frac{3}{4}$	2″	9.06
	$2\frac{5}{8}$″	$178\frac{1}{2}$	11.3	1″	$67\frac{3}{4}$	29.5	$3\frac{5}{8}$″	$246\frac{1}{4}$	$2\frac{1}{4}$″	8.12
	3″	204	9.8	1″	$67\frac{3}{4}$	29.5	4″	$271\frac{3}{4}$	$2\frac{1}{2}$″	7.36
	$3\frac{3}{8}$″	$229\frac{1}{2}$	8.7	1″	$67\frac{3}{4}$	29.5	$4\frac{3}{8}$″	$297\frac{1}{4}$	$2\frac{3}{4}$″	6.73
	$3\frac{3}{4}$″	255	7.8	1″	$67\frac{3}{4}$	29.5	$4\frac{3}{4}$″	$322\frac{3}{4}$	3″	6.2
Trap Rock	$2\frac{1}{4}$″	$168\frac{3}{4}$	11.8	1″	75	26.6	$3\frac{1}{4}$″	$243\frac{3}{4}$	2″	8.2
	$2\frac{5}{8}$″	$196\frac{7}{8}$	10.2	1″	75	26.6	$3\frac{5}{8}$″	$271\frac{7}{8}$	$2\frac{1}{4}$″	7.36
	3″	225	8.9	1″	75	26.6	4″	300	$2\frac{1}{2}$″	6.66
	$3\frac{3}{8}$″	$253\frac{1}{8}$	7.9	1″	75	26.6	$4\frac{3}{8}$″	$328\frac{1}{8}$	$2\frac{3}{4}$″	6.1
	$3\frac{3}{4}$″	$281\frac{1}{4}$	7.1	1″	75	26.6	$4\frac{3}{4}$″	$356\frac{1}{4}$	3″	5.6
Sandstone	$2\frac{1}{4}$″	$164\frac{1}{4}$	12.2	1″	73	27.4	$3\frac{1}{4}$″	$237\frac{1}{4}$	2″	8.43
	$2\frac{5}{8}$″	$191\frac{5}{8}$	10.4	1″	73	27.4	$3\frac{5}{8}$″	$264\frac{5}{8}$	$2\frac{1}{4}$″	7.56
	3″	219	9.1	1″	73	27.4	4″	292	$2\frac{1}{2}$″	6.85
	$3\frac{3}{8}$″	$246\frac{3}{8}$	8.1	1″	73	27.4	$4\frac{3}{8}$″	$319\frac{3}{8}$	$2\frac{3}{4}$″	6.26
	$3\frac{3}{4}$″	$273\frac{3}{4}$	7.3	1″	73	27.4	$4\frac{3}{4}$″	$346\frac{3}{4}$	3″	5.77

To find the amount of loose Amiesite necessary for any compressed thickness, subtract $\frac{1}{2}$ inch from compressed thickness, multiply by $1\frac{1}{2}$ which equals loose thickness, to which add 1 inch for Filler.

To find what compressed thickness any given amount of loose Amiesite will give, subtract 1 inch from loose thickness, multiply by $\frac{2}{3}$ and add $\frac{1}{2}$ inch for Filler.

Hassam Concrete Pavement.

Cost of Grouting. Road No. 5529. Lyell Ave., Spencerport. Season 1915. E. E. Kidder, Eng. in charge. Road 16′ wide 5″ deep compacted measure and approx. 6 miles long. 9880 cu. yds. of Hassam were grouted in 71 working days with the organization shown in Fig. 66 A.



	Daily Force Account	
5	Tamp & Broom-men	$12.50
1	Spout-man	2.00
1	Operator	2.75
6	Passers Etc.	12.00
1	Roller-man	3.50
1	Foreman	3.50
	Total	$36.75

FIG. 66 A

71 days @ $36.25 per day..................$2573.75
Amount grouted ....9880 cu. yds
Cost of labor per cu. yd.................. $0.26

Conditions

Administration and superintendence good. Temper of crew rather bad as they were not receiving the wages that they expected to get for the first half of the job. Could have made a better record.

Speed of Work

Averaged 450 lin. ft. per day.

Materials

Cement. 8500 bbls. used or an average of 0.86 bbls. per cu. yd. of Hassam. This varied from 0.75 in the beginning to 0.95 during the latter part of the work when a liberal spread of stone was used to compensate for rough grading and a desire to end the work before winter.

Sand. Royalty on sand was $0.30 per load or $0.052 per cu. yd. of Hassam. Cost of haul corresponds to average costs given in previous cost data.

Stone. 16050 tons of limestone $1\frac{1}{4}''$ to $3\frac{1}{2}''$ in size were used. This amounts to 3250 lbs. per cu. yds. compacted measure which is high for this grade of stone. This was due to a liberal use of stone over poorly shaped sub-grade and to excess depth where wet material was removed.

Water. Metered supply. 70 gals per cu. yd of Hassam; this includes water for engines, leakage in a long line and considerable waste at the grout mixer.

Concrete Roads. Cost Data. Rd. 5423, Hartland Medina Pt. 2. Season 1914. F. W. Bristow, Eng. in charge. 9550 cu. yds. 1: $1\frac{1}{2}$: 3 concrete pavement laid 16′ wide 6″ deep.

Materials and Equipment

Cement. Knickerbocker @ $1.18 net bags returned f.o.b. siding. 4 mile average haul.

Sand. Excellent local sand. $1\frac{3}{4}$ mile haul.

Stone. Local crushed stone (Medina Sandstone and granite $\frac{1}{2}''$ to $2\frac{1}{2}''$ in size) $\frac{1}{4}$ mile haul to crusher, 1 mile haul crusher to road.

Concrete Mixer. Koehring with boom and bucket delivery $\frac{3}{8}$ cu. yd. batch.

Speed of Work. 500 to 550 lin. ft. of road or 148 to 165 cu. yds. mixed and placed per 10 hour day.

Actual Amount of Materials Used

Cement 1.85 bbls. per c. y. concrete
Sand 0.4 c. y. per c. y. concrete
Stone 0.80 c. y. per c. y. concrete

Joints

Wooden joints used for $\frac{1}{2}$ the work.
Steel and felt joints used for $\frac{1}{2}$ the work.

Labor Cost of Mixing and placing Concrete

Labor $0.175 per 10-hour day.
The force at the mixer comprised:

1 Foreman.
2 Laborers setting forms.
10 " shoveling stone.
3 " " sand.
6 " on stone wheelbarrows.
2 " " sand "
1 " passing cement.
1 " emptying "
1 Mixer runner.
1 " fireman.
4 Laborers placing concrete.
2 " on screed.
2 " floating.
1 " preparing joints.
1 " sprinkling, brooming, etc.

The cost of setting forms, mixing, placing and finishing the concrete including coal ranged from 0.48 to 0.51 per cu. yd.

This does not include overhead or plant charge.

The water cost per cu. yd. concrete was approx. $0.04 and includes laying pipe line and pumping from creeks.

The overhead charge per cu. yd. of concrete were approx. as follows:

Bond....................................	$0.036 per cu. yd.
Employers Compensation Insurance $2.92 per $100 payroll..............................	0.096 " " "
Public Liability Insurance.....................	0.016 " " "
Machinery and tools, freight hauling, erection, interest, depreciation and repairs............	0.600 " " "
	$.748

Say $0.75 per cu. yd.

LOCKPORT CITY, MARKET ST. AND LAKE AVE. C.H. 1153

ASPHALT BLOCK COST DATA

Length = 1.27 Miles
Width = 30′ — 47′

Type: Asphalt Block
Medina Block

Date	Station–Station	Lineal Feet	Square Yards	Hours Fore.	Amount	Mortar Bed: Mixing: Eng.	Labs.	Amount	Bed-men	Placing and Striking: Labs.	Amount	Laying Block: Layers	Amount	Cutters	Amount	Cull	Amount	Carry	Amount	Sand Cover	Amount
Nov. 16	67+70 67+87.2	87.2	270 Flare	8	$5.00	8	10	$5.50	8	35	$13.75	16	$10.00	....	......	5	$1.25	35	$8.75	...	.....
" 17	65+42 67+70	228	760	8	5.00	8	24	9.00	8	64	21.00	16	10.00	24	$6.00	24	6.00	56	14.00	...	.....
" 18	61+82 65+42	360	1200	8	5.00	8	32	11.00	16	72	28.00	32	20.00	40	10.00	16	4.00	112	28.00	32	$8.00
" 19	60+97 61+82	85	284	8	5.00	2	8	2.76	4	14	6.00	10	6.25	10	2.50	2	.50	36	,9.00	...	.....
		Olcott St.																			
" 20	57+85 60+97	312	1205	8	5.00	8	32	11.00	16	56	24.00	40	25.00	40	10.00	8	2.00	128	32.00	...	.....
" 21	53+95 57+85	390	1300	8	5.00	8	32	11.00	16	56	24.00	40	25.00	40	10.00	8	2.00	112	28.00	...	.....
		Clinton St.																			
" 22	51+60 53+95	235	1008	8	5.00	8	40	13.00	16	72	28.00	40	25.00	40	10.00	8	2.00	112	28.00	40	10.0
" 23	47+25 51+60	435	1450	8	5.00	8	40	13.00	16	72	28.00	40	25.00	40	10.00	8	2.00	112	28.00	40	10.00
		Flare St.																			
" 24	44+75 47+25 35+00 35+65	315	1106	8	5.00	8	40	13.00	16	72	28.00	40	25.00	40	10.00	8	2.00	112	28.00	40	10.00
" 25	31+60 35+00	340	1274	8	5.00	8	40	13.00	16	72	28.00	40	25.00	40	10.00	8	2.00	112	28.00	40	10.00
" 26	30+00 31+60	160	534	8	5.00	8	35	11.75	14	28	15.75	35	22.00	35	8.75	14	3.50	84	21.00	40	10.00
" 27	28+75 30+00	125	418	8	5.00	2½	12½	4.06	5	10	5.38	12½	7.81	12½	4.06	5	1.25	30	7.50	...	.....
		Adam St.																			

"	28	25+50	28+75	325	1192	8	5.00	8	40	13.00	16	32	18.00	40	25.00	40	10.00	16	4.00	96	24.12	40	10.00
"	29	24+15	25+50	135	450	8	5.00	4	20	6.50	8	48	17.00	16	10.00	20	5.00	8	2.00	48	12.00	80	20.00
"	30	21+55	24+15	260	870	8	5.00	8	32	11.00	8	24	11.00	16	10.00	40	10.00	...	.....	96	24.00	40	10.00
Dec.	1	20+36	21+55	119	471	8	5.00	8	48	15.00	6	12	6.75	12	7.50	24	6.00	...	.....	102	25.50	8	2.00
"	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	40	10.00
"	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	40	10.00
"	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	40	10.00
"	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	40	$10.00
					13776	128	80.00	112½	485½	163.57	189	443	302.63	445½	224.06	485½	122.31	138	34.50	1383	345.75	560	140.00

Total Cost
$1912.82

ASPHALT BLOCK
Engineer's Estimate

Block at Mfg. Plant, Lockport	= $0.96	sq. yd.
Haul ½ Mile	= 0.03	" "
Sand	= 0.02	" "
Cement	= 0.03	" "
On and off	= 0.04	" "
Lay and Roll	= 0.07	" "
Cushion	= 0.04	" "
	1.19	" "
Profit	= .18	" "
	1.37	" "
Use $1.40		

MORTAR BED { Mixing = 163.57 = $0.019 per sq. yd.
Paving = 302.63 = 0.022 " " "

Total Bed = 0.041 " " "

Estimate Based on Cost Data C.H. 1153

Blocks F.O.B. Lockport (Boots)	= $0.90	per sq. yd.
On and off	= 0.04	" " "
Haul ½ Mile	= 0.03	" " "
Sand	= 0.03	" " "
Cement	= 0.05	" " "
Lay	= 0.10	" " "
Mortar Bed	= 0.04	" " "
Carr'd For'd	1.19	" " "

BLOCK { Carrying = 345.75 = $0.025 per sq. yd.
Laying = 724.06 = 0.053 " " "
Cutting = 122.31 = 0.009 " " "
Culling = 34.50 = 0.003 " " "
Sand = 140.00 = 0.010 " " "

Total Cost = 0.100 " " "

Bro't For'd	$1.19	per sq. yd.
Profit 10% Material	.10	" " "
" 20% Labor	.04	" " "
	$1.33	" " "

Contract Price $1.37

COST, DATA, CONCRETE ROADS

Materials

Stone. Cost of stone varied greatly during the year, from 62¢ to 85¢ per cu. yd. at the Blissville docks. To obtain a low voidage contractors ordered a mixture of No. 2 and No. 3 stone. This mixture weighed approximately 2700 lbs. per cu. yd.; therefore, cost of stone f.o.b. car at destination would be

1 cu. yd. stone at Blissville (say)	$0.80
Transfer (17¢ per ton), 1.35 x .17	.23
Freight (63¢ per ton), 1.35 x .63, (rate to Patchogue)	.85
Total	$1.88

NOTE: Arrigoni paid $1.81 delivered f.o.b., on rate made in 1914, before stone dropped. Freight rate to Patchogue then 60¢.

Haul varied from 12¢ per yd. mile using tractor-roller and 5 cu. yd. trailers (3), to as high as 35¢ per yd. mile with teams.

Transfer from cars to wagons 15¢ to 20¢ per cu. yd. dependent mostly on rate of wages; therefore, cost on job, with stone as per above, and a two-mile haul would be approximately $1.88+.60+.20 =$2.68 per cu. yd.

Gravel. Cost of same at bank, screened, and in bin varied from 45¢ to 85¢ (dependent mostly on per cent of gravel). Haul: same as stone.

Sand. Cost of same at bank (in wagons. Screening unnecessary) varied from 35¢ to 60¢.

Haul: 25¢ to 35¢ per yd. mile.

NOTE. When obtained from same pit as gravel I would consider its cost in bin as ⅓ the cost of all material leaving the plant, gravel in this case ⅔ of same total (say 25¢ [sand] and 50¢ [gravel] where gravel would be 75¢+ were all sand wasted).

Cement. Cost of cement varied greatly during the year; a good average was $1.20 per bbl. net. Actual practice with graded stone has shown 1.75 bbls. per cu. yd. of concrete a safe factor.

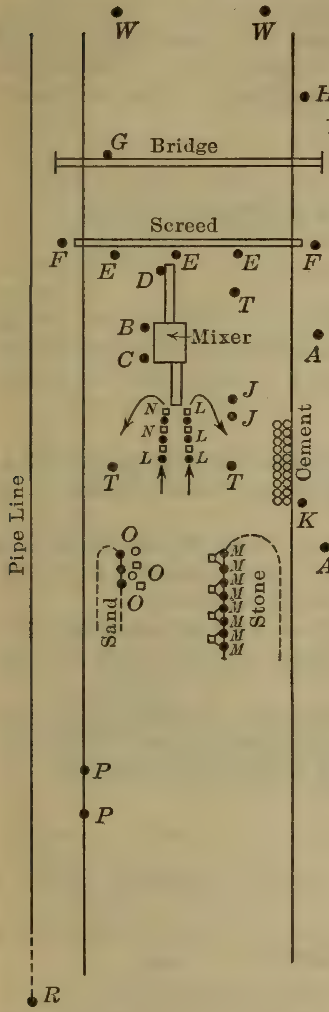
Haul varied from 3½¢ (truck) to 5¢ (wagon) per bbl. mile.

Handling: average 2¢ per bbl. when handled direct from car to job.

Plant. Exclusive of forms and water-line.

1 Mixer — 4 bag mix, 1–1½–3, at least 20 cu. ft. capacity.
1 Screed — 19′ by 4″ by 12″, with ¼″ iron plate.
1 Bridge — 18′ x 3″ x 12″.
3 floats — (one split); and one trowel.
1 doz. Forks — close tined for stone.
10 Square Shovels.
16 Wheel-barrows (2 or 2¼ cu. ft. capacity).
1 Canvass — 160′ x 20′ — with frame.
2 Tampers.
1 Template to test sub-grade.
1 doz. Pins to hold expansion joints (or special template for that purpose).
Small tools, other than noted.

1 Straight-edge, 24 × 10″ × 4″, for extra width on curves.
Total cost of above approximately $2300.00.



Organization

Concrete 1-1½-3, 4 bag batch

Letter	Position	Number	Rate
A	Foreman	2	$3.00 & 4.00
B	Engineer	1	3.00
C	Fireman	1	2.50
D	Chute	1	2.00
E	Placing cone	3	2.00
F	Screeding	2	2.00
G	Floating	1	2.50
H	Brooming and general help	1	1.85
J	Cement (to hopper)	2	2.00
K	Cement (getting ready)	1	1.85
L	Stone (barrows)	4 or 5	1.85
M	Stone (shoveling)	8	1.85
N	Sand (barrows)	2 or 3	1.85
O	Sand (shoveling)	3	1.85
P	Forms	2	2.00
R	Pump	1	2.25
T	Trimming grade	3	1.85
W	Watchmen, covering and wetting down	2	1.85

Also charge ½ Supt. and ⅓ timekeeper

Trimmers "*T*" place expansion joints

FIG. 66 B

Manipulation

Exclusive of water, forms and trimming sub-grade.

Supt. (½)	3.00
Time keeper (⅓)	1.00
Foremen (2) (see Fig. 66 B)	7.00
Engineer (1) (" " ")	3.00
Fireman (1) (" " ")	2.50
Mason (1) (" " ")	2.50
Laborers (8 at 2.00) (see Fig. 66 B)	16.00
Laborers (21 at 1.85) (" " ")	38.85
Total	$73.85

Based on an average day's work of 182 cu. yds. (10-hour day), the manipulation of a cubic yard of concrete would cost with the above organization, $.406.

NOTE. The above organization has laid over 780 lin. ft. of $16\frac{1}{2}$ ft. pavement (outside dimensions), in a 10-hour day. (The 182 cu. yds. is based on a length of 600′ of pavement with a cross-section of 8.2 sq. ft.)

Water

Plant should be capable of supplying 30 gallons per minute.

Pipe: 10,000 (at least) lin. ft. 2″ pipe, galvanized at 16 cents	$1600.00
Black, at $14\frac{1}{2}$ cents	1450.00
35 "Ts" for same (one each 300′) at 50¢	17.50

Pumps: 3 to 25 H.P., dependent on conditions. For lower power, gas engine O. K.; for higher, steam the best (latter, best for surety of supply).

Outfits $150.00 to $1000.00

Where wells were necessary, 2″ supply pipe. Driving same $1.40 per ft. for depths not greater than 40′; $1.50 to 70′ depth. This includes pipe and point.

Shaughnessy paid a lump sum for water from Bayshore to Islip ($300.00, I believe) from hydrants. On 5232A, water was bought from private parties for part of the work at $3.00 per day.

Cost of running steam pump located at well or surface water supply, including operator, varies from $5.00 to $8.00 per day dependent on weather conditions.

200′ of rubber hose at $0.34 per ft. necessary for connection with mixer and sprinkling road. Of this a 15-foot section should be connected on intake pipe of mixer, with which to sprinkle sub-grade.

Forms

1. 6″ Channel forms (steel) 32¢ per ft. including pins, 8′ sections.
2. Patent steel forms with bevel, 24¢ per ft. Pins for same $1.00 each, one necessary for each section. Sections 12′ long.
3. Wooden forms with bevel about 12 cents per lin. ft.

Cost of placing same, 2 men at $2.00 per day, $4.00 per day (see "P," Fig. 66 B).

At least 1200 ft. of forms necessary, so that 600 lin. ft. of road can be built without forms being moved. Based on (2) forms would cost

1200′ of forms	$288.00
Say 110 pins	110.00
Total	$398.00

Trimming Sub-grade

Three men generally necessary at $1.85 per day (see T, Fig. 66 B).

General

A steam roller ($2200.00) might justly be, partially at least, charged to concrete. Cost of operating same, including rollerman, not greater than $12.00 per day if owned by contractor.

CONCRETE COST DATA

Name of Road, Main Street, Sec. III, County Highway No. 130. (Erie County, New York State)

Length, 3.68 miles. Thickness, average 7″ parabolic crown.
Width, 16′. Proportions of mix, 1–1½–3.
Total No. Cu. Yds., 7038.

1.	Labor, exclusive of water supply, including supervision.	.6818
2.	Plant forms and tools	.3091
3.	Expansion joint material { Steel plates .1782; Tarred paper .0295; .2077 }	.2077
4.	Water supply, including labor	.0625
5.	Cement placed on roadside ready for mixer	2.3379
6.	Sand " " " " " "	.8359
7.	Stone " " " " " "	1.0518
8.	Reinforcement, if any	0000
	Total cost per cu. yd.	5.4867

Labor, rate per hour, 16½¢; Teams, rate per hour, 50¢; Hours in day worked, 10.

Remarks: Work done by State day Labor. Materials unloaded by hand. Plant Charges included proportionate to life of plant. Seven-tenths mile average haul.

Name of Road, Huntington-Amityville, Pt. 2, No. 1219 (Suffolk County).

Length, 4.69 miles. Thickness, 4¾″ and 6¾″ = av. 5¾″.
Width, 16′. Proportions of mix, 1–1½–3.
Total No. Cu. Yds., 7409.

1.	Labor, exclusive of water supply, including supervision	$.52
2.	Plant forms and tools	.58
3.	Expansion joint material	.05
4.	Water supply, including labor	.10
5.	Cement placed on roadside ready for mixer	2.36
6.	Sand " " " " " "	.23
7.	Stone Gravel " " " " "	1.05
8.	Reinforcement, if any,	0000
	Total per cu. yd.	$4.89
	Contractor's Bid Price	5.30

Labor, rate per hour, 20¢; Teams, rate per hour, 55¢; Hours in day worked, 10.

Remarks: Auto truck for most of haul. Gravel furnished by large screening and washing plant accounts for high plant cost. Only proportionate part charged for this plant as it is to be used to produce commercial output.

Road No. 1201 — Nassau County

(1) *Sand:*	
In bins Heling Bros. per cu. yd.	$.15
Haul by auto (contractor owner) $2\frac{1}{2}$ mi. at .15	.38
Sand on road per cu. yd.	.53
Gravel:	
In bins Heling Bros. per cu. yd.	.85
Haul by auto (contractor owner) $2\frac{1}{2}$ mi. at .15	.38
Gravel on road per cu. yd.	$1.23
Cement:	
Cement stored at $1.00 per day for 150 days	$150.00
Approximately 1170 bbls. stored. Storage per bbl.	.13
F.o.b. Farmingdale (est.)	1.30
Handling and hauling (.10 est.) double handling in most cases	.10
Cement per bbl. on road	$1.53
This price also approx. cost of cement bought from Parker, Hassam Co.	
Plant:	
(2) 1 auto truck (Sauer)	$6,500.00
1 Concrete mixer	1,200.00
2 doz. shovels	21.00
2 teams at $700., 2 bottom dumpers at $400.	2,200.00
Forms (wooden) 800 lin. ft.	40.00
8 barrows	24.00
2 doz. picks	42.00
1 bucket conveyor, loader	600.00
1 Screed	15.00
Incidentals	20.00
	$10,672.00
(3) Pressure water from fire plugs	
Pavement per cu. yd. canc. .10	$100.00
1500 ft. (lin.) 2″ pipe at .08	120.00
100 ft. 2″ rubber hose	50.00
300 ft. 1″ rubber hose	45.00
	$315.00
(4) Manipulation per cu. yd. in place. This does not include covering, uncovering, sprinkling	.92
(5) *Forms:*	
Setting and re-setting forms per lin. ft. of road	.03

$$\frac{3 \times 1.75 \times 20 \text{ days}}{3093} = .03$$

(6) *Trimming:*

Per cu. yd. of concrete	.28

6 men @ $1.75 20 days = $210
roller @ 12. 6 " = 72

$$\frac{\$282}{990} = .28$$

cu. yd. of conc.

Expansion joints at 40¢ apiece every 30 ft.

Covering and uncovering and wetting concrete during curing season

2 men to cover @ $1.75	$3.50
2 men to uncover at $1.75	3.50
1 man to sprinkle	1.75
	$8.75

$$\frac{8.75 \times 20}{990} = .18 \text{ per cu. yd. conc.}$$

Road No. 1203 — Nassau County

(1) *Sand:*

In Pit of Mr. Bennett per cu. yd.	$.15
Screening and loading (estimated)	.22
Haul 2 mi. (auto truck) contractor owner @ .12	.24
Cost per cu. yd. on road	$.61

Trap Rock (Imported)

F.o.b. Baldwin $1.59 per cu. yd.	$1.59
Unloading 15¢	.15
Haul 1.6 mi. at 25¢ teams and auto truck	.40
Stone per cu. yd. on road	$2.14

Cement:

F.o.b. Baldwin per bbl.	$1.38
Handling and hauling per bbl. .05	.05
Cement per bbl. on road	$1.43

(2) *Plant:*

1 Screed	$ 20.00
1 Concrete Mixer	1800.00
1 Steam Roller	3000.00
1 doz. Wheelbarrows	36.00
2 doz. Shovels	21.00
3 Teams at $700, 3 Bottom Dumpers at $400	3300.00
1 Auto Truck	5000.00
2 doz. Picks	42.00
Forms (wooden $20.00; steel $126.00,)	146.00
Incidentals	50.00
Water Wagon	400.00
	$13,815.00

Water:	
Pressure line fire plugs, total	$100.00
4000 ft. 2″ pipe .06	240.00
100 " " rubber hose	50.00
300 " 1″ " "	45.00
	$435.00
(4) *Manipulation:*	
Includes all work, sprinkling, covering, uncovering, in place complete per cu. yd.	$.67
(5) *Forms:*	
Setting and resetting forms per lin. ft. of road	.05
(6) *Trimming* (Sub-grade)	
Per cu. yd. concrete in place	.24
Expansion Joints at 40¢ apiece every 30 ft.	

Road No. 1219 — Suffolk County

(1) *Sand:*	
In bins Heling Bros. pit cu. yd	$.10
Haul by auto (contract) 1.5 mi. est. .30	.30
Cost per cu. yd. on road	$.40
Gravel:	
In bins Heling Bros. pit cu. yd	$ .75
Haul by auto (contract) estimated .30	.30
Cost per cu. yd. on road	$1.05
Cement:	
Bbl. f.o.b. Farmingdale	$1.27
Handling and hauling	.08
Cement on road per bbl	$1.35
(2) *Plant:*	
Same as on No. 1218	
(3) *Water:*	
Cost of water	$700.00
1 mile 2″ pipe at .06 per. ft	320.00
100 ft. 2″ rubber hose	50.00
400 ft. 1″ " "	60.00
1 pump and gas engine (est.)	1,000.00
	$2,130.00
(4) *Manipulation:*	
Includes all work; sprinkling, covering, uncovering, in place complete per cu. yd.	$.50
(5) Forms, setting and reset ing per lin. ft. of road	.02
(6) *Trimming:*	
Per lin. ft. of road	.06
Expansion joints at 40¢ apiece every 30 ft.	

Road No. 1218 — Suffolk County

(1) *Sand:*	
In bins Heling Bros. pit cu. yd.	$.10
Haul by auto (by contract) 1.7 mi. approx.	.40
Sand per cu. yd. on road	$.50
Gravel:	
In bins Heling Bros. pit cu. yd.	$ .75
Haul by auto (by contract) approx.	.40
Cost per cu. yd. on road	$1.15
Cement:	
F.o.b. Farmingdale	$1.27
Handling and hauling	.08
Cement on road per bbl.	$1.35
(2) *Plant:*	
Gravel and sand screening complete, including various set ups	$15,000.00
1 Concrete Mixer	1,800.00
1 Roller	2,800.00
1 Screed	20.00
18 Wheelbarrows	54.00
2 doz. Shovels	21.00
3 teams @ $700, 3 bottom dumpers @ $400	3,300.00
2 doz. Picks	42.00
1 rd. Planer and Scarifier	600.00
Forms (steel)	630.00
Tarpaulins	100.00
Incidentals	75.00
	$24,442.00
(3) *Water:*	
Total paid for water approx.	$130.00
1 mile 2″ pipe at .06	320.00
100 ft. 2″ rubber hose	50.00
400 ft. 1″ " "	60.00
	$560.00
(4) *Manipulation:*	
Includes all work, sprinkling, covering, uncovering, in place complete per cu. yd.	$.54
(5) *Forms:*	
Setting and resettimg forms per lin. ft. of road	.02
(6) *Trimming:*	
Per lin. ft. of road	.06
Expansion joints 40¢ apiece every 30 feet.	

COST DATA

Name of Road, Huntington Town Line-Farmingdale, Part 1 (Suffolk County)

Length, 1.27 miles. Thickness, 5″ & 7″ = Av. 6″.
Width, 16′. Proportions of mix, 1–1½–3.
Total No. Cu. Yds. 2051.

1.	Labor, exclusive of water supply, including supervision	$.56
2.	Plant forms and tools	.61
3.	Expansion joint material	.06
4.	Water supply, including labor	.12
5.	Cement, Placed on roadside ready for mixer	2.13
6.	Sand, " " " " " "	.22
7.	Stone, " " " " " "	1.01
8.	Reinforcement, if any	0000
	Total per cu. yd.	$4.71
	Contractor's Bid Price	5.30

Labor, rate per hour, 20¢; Teams, rate per hour, 55¢; Hours in day worked, 10.

Remarks: Auto truck for most of haul. Gravel furnished by large screening and washing plant accounts for high plant cost. Only proportionate part charged for this plant as it is to be used to produce commercial output.

Road No. 1202 — Nassau County

(1) *Sand:*

Estimated at .10 per cu. yd. in bins	$.10
Haul (by contract) estimated at .40 per cu. yd.	.40
	$.50

Gravel:

Stiff leg derrick set up (in bins)	$2.00
Haul (by contract) estimated at .40 per cu. yd.	.40
1st set up per cu. yd. on road	$2.40
Drag line set up per cu. yd.	$1.20
Haul (by contract) estimated .40 per cu. yd.	.40
2nd set up per cu. yd. on road	$1.60
Imported gravel per cu. yd. scow L. I. City	.85
Unloading from scow L. I. City	.15
Freight L. I. City to Central Park	.78
Unloading at Central Park	.10
Haul (by contract) at .20 per cu. yd.	.20
Cost per cu. yd. on road	$2.08

Average cost per cu. yd. on road $1.92.

Cement:	
Bbl. f.o.b. Central Park {estimated by market}	$1.20
Haul by contract per. Bbl.	.06
Handling	.02
Per Bbl. on road	$1.28
(2) *Plant* estimated.	$12,000.00
(3) *Water:*	
Cost of water.	$1,000.00
4 mile 2″ pipe at $0.06 per ft.	1,270.00
100 ft. 2″ rubber hose at $0.50.	50.00
400 ft. 1″ " " at $0.15.	60.00
1 pump, boiler, etc.	1,000.00
	$3,380.00
(4) *Manipulation:*	
Includes all work, sprinkling, covering and uncovering; in place complete per cu. yd.	$.64
(5) *Forms:*	
Setting and taking up per lin. ft. of road.	.04
(6) *Trimming:*	
Per lin. ft. of road	.075
Expansion joints at 40¢ apiece every 30 ft.	

COST DATA

Name of Road, Little Valley-Cattaraugus, Part 1 (Cattaraugus County)

Length, 5.35 miles. {3900 lin ft. 16 ft. / 9700 " " 14 ft.}

Thickness, {6″ & 8″ = Av. 7″. / $5\frac{1}{4}$″ & 7″ = Av. $6\frac{1}{8}$″.}

2.575 miles completed.

Width, 16 and 14. Proportions of mix. 1–$1\frac{1}{2}$–3.

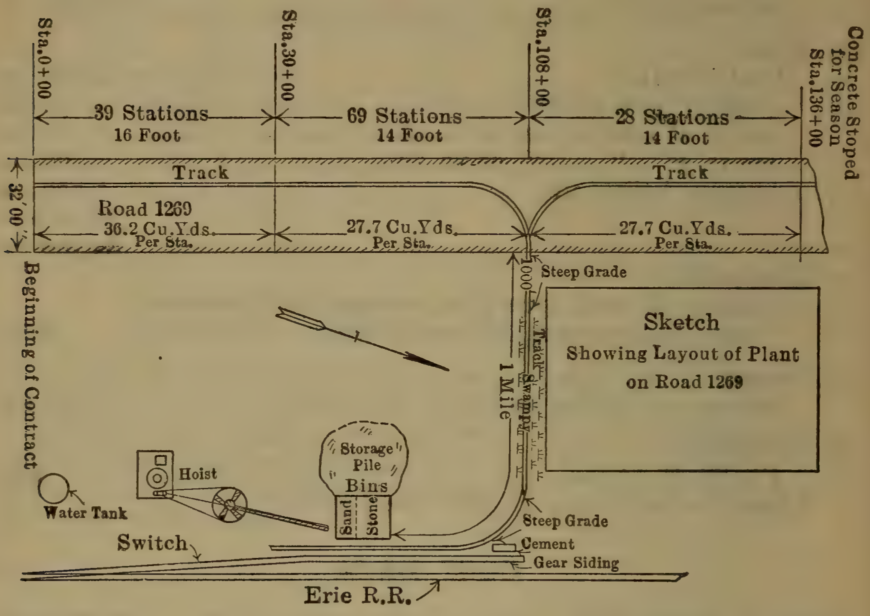
Total No. Cu. Yds. 8280 — This cost covers 4165 cu. yds.

1. Labor, exclusive of water supply, including supervision.	.423
2. Plant forms and tools. .662 + .158 for coal.	.820
3. Expansion joint material.	.045
4. Water supply, including labor.	.030
5. Cement, placed on roadside ready for mixer	1.984
6. Sand, " " " " " "	.522
7. Stone, " " " " " "	1.505
8. Reinforcement, if any.	0000
Total cost per cu. yd.	5.324
Contractor's Bid Price.	6.30

Labor, rate per hour, 18½¢; Teams, rate per hour, None used; Hours in day worked, 10.

Remarks: Industrial Ry. Plant delivering sand, stone and cement into hopper of concrete mixer, clam shell unloader used to take material off cars. Material delivered alongside mixer in buckets proportioned for one batch size.

For plant layout see illustration



Plant Layout

COST OF CONCRETE WORK

The following data will help in estimating the cost of small concrete jobs, such as culverts, walls, etc. This data was collected by Mr. E. E. Kidder during the season of 1908. Table 49 contains the theoretical proportions of cement, sand, and stone required for the three ordinary mixtures of concrete. These values were found by experience to agree with actual proportions very closely for ½" to 1¼"-stone. (Continued page 304.)

Little Valley-Cattaraugus Part I. — C. H. No. 1269

Cement Concrete Pavement. — 3900 Ft. of 6″ and 8″–16 Ft. and 9700 Ft. of $5\frac{1}{4}$″ and 7″–14 Ft.

Item	Amount	Amt. per Cu. Yd. Conc.	Amt. per Unit	Avg. Haul	Per Yd. Amount	Concrete		Haul		Unloading		Remarks
						Unload	Haul	Yd. Mi.	TonMi.	Yd.	Ton	
Cement (Net)	$8036.00	$1.930	$1.00 bbl.	1.95 mi.	1.93 bbl.	.023	.031					
Sand	1837.50	0.441	1.05 yd.	1.95 "	0.42 yd.	.035	.046	.0565	.043	.082	.063	
Stone	5547.04	1.332	1.23 ton	1.95 "	0.9 yds.	.074	.099					
Joints	187.95	0.045	0.028 ft.									Includes Setting Forms, Covering and Watering Conc.
Manipulation	1764.00	0.423										
Unloading	549.50	0.132										
Hauling	735.00	0.176										
Coal (240 ton)	660.00	0.158	2.75 per ton	(Assumed)								
Water	124.92	0.030										

$4.667 — Cost per Cu. Yd. Excluding Cost of Plant. (See Below)

Plant

Hauling

Item	No.	Cost per	Amt.	
Dinkey Engines	3		2,500.00 Est.	Second Hand
Buckets	90	$6.50 each	585.00 Act'l	New (Wooden)
Track	20,000 ft.	0.26 ft.	5,200.00 "	Second Hand
Trucks	30	25.00 each	750.00 Est.	" "
Kopples	6	50.00 "	300.00 "	" "
			$9,335.00	

Note. Values attached to plant are estimated by Engineer where noted.

Unloading

Bins	1 Double	$1000.00 Est.	Pictures 1 and 2
Derrick and Hoist		1800.00 "	
		$2800.00	

Manipulation

Mixer (Austin Cube)	½ Yd.	$1900.00 New	Picture 5

Total Cost of Plant = $14,035.00

TABLE 49.—MATERIALS REQUIRED FOR 1 CU. YD. OF CONCRETE

Mixture	Cement	Sand	Stone
1-2-4	1.5 bbls.	0.4 cu. yds.	0.9 cu. yds.
1-2½-5	1.2 "	0.45 " "	0.92 " "
1-3-6	1.0 "	0.45 " "	0.95 " "

The amount of water used per cu. yd. of concrete will vary greatly. A plastic mixture usually requires about 30 gals. per cu. yd., according to Baker, 40 gals. according to Barnes.

Where boulders are embedded in the foundations and side walls of small culverts similar to Plate 6, less cement, sand, and stone are required; our experience with work of this kind shows that only 0.8 to 0.9 bbls. of cement are needed per cu. yd. for the total amount of concrete in these culverts including cover and parapets. For all classes of work where boulders cannot be embedded these proportions are about right.

	Per Cu. Yd.
Forms (labor)	$0.58
Lumber	0.50
[1] Labor, mixing, and placing	1.18
[1] Foreman	0.20
[1] Broken stone, at crusher	0.90
[1] Hauling stone, one mile	0.30
Sand at pit at 65 cts. per cu. yd.	0.32
Hauling sand six miles	0.75
[1] Taking down forms	0.10
Cement at culverts	2.00
Total	$6.83

Labor, $0.15 per hour.

Concrete, hand-mixed.

200 cu. yds., placed in small culverts, averaging 12 to 15 cu. yds. each.

NOTE. The labor of placing the concrete is customarily sublet to masons for $2.00 per cu. yd.

Small Culverts.

Java Center Road. George A. Wellman, Engineer.

One hundred and sixty-one cu. yds. of concrete in culverts, averaging 12 to 20 cu. yds. each.

Boulders were embedded in the third-class concrete. Water only had to be hauled for 30 cu. yds. of concrete.

[1] Items accurate; other items approximately correct.

Item	Materials Total Quality	Unit Cost	Total Cost	Amt. Per Cu. Yd. of Concrete Material	Costs
Cement	138 bbls.	$1.12	$154.56	0.86 bbls.	$0.96
[1] Sand	60 cu. yds.	1.00	60.00	0.37 cu. yds.	0.37
Crushed stone	130 " "	1.55	201.50	0.80 " "	1.24
Lumber	3 M	30.00	90.00		0.56
			Total		$3.13

Costs are f.o.b. unloading point; teaming of material included in the labor cost given below, except for sand, which cost $1.00 delivered on the job. Concrete mixed and placed by hand.

Item. Cost of Labor and Teaming	Total	Per Cu. Yd. of Concrete
Foreman	$93.00	$0.58
Labor, unloading stone from cars	20.00	0.12
Mixing, placing concrete, and removing forms	204.00	1.27
Carpenters, building forms	75.00	0.47
Teaming	182.00	1.13
	Total Labor	$3.57
	Total Material	3.13
	Total	$6.70

Labor	$0.175	per hour
Teams	0.50	" "
Carpenters	0.25	" "
Foreman	0.30	" "

Small Span Concrete Arch. The following information of cost of 19-ft. span concrete arch was given by Mr. Charles M. Edwards, First Assistant Engineer, New York State Department of Highways. Arch was built at Pembroke, N.Y., by a contractor who was crushing stone at a quarry about one-half mile from the work. Cement was hauled three-quarters of a mile. For the concrete a mixture of one part Portland cement, two parts sand, and four parts stone was used. The old masonry abutments and wings were left in place and faced with 8 inches of concrete held by dowels. The quantities were: Concrete, 120 cu. yds.; steel bars, 4,500 lbs.; pipe railing, 200 lin. feet. The cost of the work was as follows:

Lumber, including arch centers	$156.00	on job
Steel	106.00	" "
Cement	137.00	on siding, f.o.b.
Stone	240.00	on job
Dust and sand	90.00	
Railing	78.00	f.o.b. siding
Labor	300.00	
Total	$1,107.00	

[1] The sand on this job cost practically nothing but we have placed the cost at $1.00 in order to avoid a misleading item.

Omitting the cost of railing this figure gives a cost of $8.57 per cu. yd. of concrete, including steel. This cost does not include salvage of lumber or overhead expenses of any kind. The contractor received $1,500.00 for the work, including the earth filling, for which he used quarry strippings. This filling cost about $50.00.

Guard-Rail. In the following data the labor cost alone is given, for the materials will vary so much at different times and places that any quotations would be of little value.

The style of rail erected is similar to sketch, page 86. Road 715, 9,760 lin. ft. were built at the following cost, according to S. O. Steere, engineer in charge: Post-hole auger-diggers and ordinary shovels were used; the holes were dug in medium hard clay; labor at $0.20 per hour, foreman $3.00 per day; unskilled labor used in painting fence.

Digging post holes, setting posts, nailing on rails (erecting fence complete):

Cost	$0.0428	per lin. ft.
Painting three coats	0.0094	" " "
Total for erecting and painting	$0.0522	" " "

Road 5,046, W. G. Harger, as Engineer. 2,448 lin. ft. Built by subcontractor, Max Weller.

Force: Max Weller acted as foreman. In this data he has been arbitrarily allowed salary of $4.00 per day $4.00

1 helper	2.50
1 helper	2.00
1 helper	1.75

Cost of erecting and painting complete, per lin. ft. $0.066.

In Report of 1901 the Massachusetts Highway Commission gives the following costs for repainting guard-rail:

Lineal feet of guard-rail painted	350,330
Cost of paint per gal. (freight not included)	$1.05
Cost of paint per lin. ft. of guard-rail	0.0084
Cost of paint and painting per lin. ft. of guard-rail	0.0165
Lin. ft. of guard-rail painted per gal.	134.4
No. gals. of paint used per lin. ft. of guard-rail	0.0077
Time required to paint one foot, in decimals of an hour	0.0269

Concrete Guard-Rail. Style of rail shown in sketch on page 87, chapter on Minor Points.

Labor, $0.225 per hour.

Cost of manufacturing 1,233 lin. ft. of rail of the above description. Taken from the Report of the New York State Highway Commission of 1910.

Lumber	$ 32.46	$0.026	per lin. foot.
Steel	139.64	0.114	" " "
Cement	57.62	0.046	" " "
Gravel	10.00	0.008	" " "
Metal cores	77.00	0.063	" " "

Labor	231.83	0.188	" " "
Miscellaneous	5.35	0.004	" " "
Total	$553.90	0.449	

This data applies to small quantities; if manufactured on a large scale the cost should be reduced to about $0.30 per lin. ft.

The cost of setting the above rail varied from $0.09 to $0.125 per lin. ft: labor $0.225 per hour. This does not include hauling from the factory to the intended position on the road.

Cobble Gutter. Road 5,046, W. G. Harger, Engineer.

Labor, $0.175 per hour. Foreman, $3.50 per day.

Cobbles averaged 6 in. in size; no sand cushion required, as gutter was built in a sand cut. Gutter was laid by ordinary laborers using paver's tools; tamped with a paving rammer, and the top voids filled with No. 2 stone crushed on the job.

430 sq. yds. were laid at the following cost per sq. yd.:

Cobbles, free	$0.000
Loading $\frac{1}{6}$ cu. yds. of cobbles	0.030
Hauling $\frac{1}{6}$ " " " $\frac{1}{2}$ mile	0.024
Laying and tamping	0.080
Filler. Cost of 0.05 cu. yds. No. 2 stone at crusher bin, approximately	0.030
Hauling 0.05 cu. yds. 1 mile	0.015
Spreading and brooming, 0.05 per cu. yd. No. 2 stone	0.010
Total	$0.189

PRICES OF VITRIFIED PIPE

The discounts vary, but if no quotations of current prices are available the following list will serve for an approximate estimate:

[1] Eastern List

Size	Discount
3″ to 24″	88%
24″ and 30″	80%
33″ and 36″	75%

At these discounts the net prices per foot in car-load lots f.o.b. factory are:

Size	Price	Size	Price
3″	$0.024	20″	$0.270
4″	0.030	21″	0.325
5″	0.036	22″	0.360
6″	0.048	24″	0.390
8″	0.066	27″	0.900
10″	0.096	30″	1.100
12″	0.120	33″	1.560
15″	0.162	36″	1.750
18″	0.227	—	—

[1] *Engineering News*, April 4, 1912.

TABLE 50.—SPEED OF WORK, VALUE OF PLANT, FORCE ACCOUNT. SUMMARY OF PLANTS AND FORCE ACCOUNTS

Road No.	Style of Road	Local or Imported Stone	Kind of Hauling	Weekly Force Account	Value of Plant	Speed of Work Miles per Month
1	16-ft. Bit. Mac.	Imported	Mechanical and teams	$1,000	$13,500	0.7
2	16 " " "	"	Mechanical	800	13,600	0.7
3	16 " " "	"	Teams	900	8,000	0.5
4	16 " " "	"	"	1,000	8,000	0.6
5	16 " " "	"	"	—	4,500	0.4
6	16 " " "	" top (local bot.)	"	1,900	14,500	1.3
7	16 " " "	Local	Teams and Mechanical	600	12,000	0.5
8	16 " " "	"	Teams	1,000	9,000	0.5
9	16 " " "	"	"	600	9,000	0.6
10	16 " Water Mac ..	"	"	1,600	10,000	1.2
11	16 " " " ...	"	"	1,000	10,500	0.8
12	16 " " " ...	Imported	"	1,000	6,000	0.7
13	14 " " " ...	"	"	1,200	12,600	0.7
14	16 Resurfacing	"		500	5,000	1.5

Labor, $0.16 to $0.20 per hour. Average $0.175. Teams, $0.40 to $0.50 per hour. Average $0.45.

PLANT AND PAY-ROLL

Table 50, page 252, shows in a convenient form the value of plants and the largest weekly force account of two months' duration on fourteen roads in New York State. From this and other information it is reasonable to assume that a contractor has tied up, outside of money on plant and materials, from $5,000 to $8,000 for the full length of time that the work is in progress, and for short periods he may have as high as $15,000 or $20,000 invested.

Interest, Depreciation, Repairs, etc. To the best of my judgment the following estimates show about the amount of money required on the different styles of construction noted. These data are based on an outfit which would be capable of a speed of about 0.7 mile per month, or five miles in a season.

Adopted Value of Plant Items

Item	Value	Life	Annual Repairs
10-ton roller	$2700	20 yrs.	$70.00
Brick roller	1800	20 "	40.00
Traction-engine	1200	8 "	100.00
Crusher	900		
Elevator	200	8 "	400.00
Bin and screen	500		
5 H.P. gasoline engine	250	8 "	50.00
Gas engine and pump	200	5 "	50.00
6000 ft. of pipe	600	say 10 "	10.00
Wagons	115	6 "	10.00
Hand tools	150	1 "	—
Plows	100	3 "	—
Road machine	200	5 "	10.00
Tar kettle	$125–200	—	[1] 10.00
Wheel scraper	70	5 "	10.00
Slush scraper	6	5 "	—
10-ton roller used for hauling	2700	10 "	200.00
Hauling traction-engine	2200	8 "	200.00

[1] Including new tank every three years.

6% INTEREST AND DEPRECIATION ON PLANT ITEMS

ITEM	Interest	Depreciation
Roller	$162.00	$135.00
Traction-engine	72.00	150.00
Crusher	54.00	100.00
Elevator	12.00	30.00
Screen	3.00	50.00
Bin	30.00	40.00
Gasoline engine	15.00	30.00
Gasoline pump	12.00	40.00
6000 feet 1½" pipe	36.00	60.00
Wagons	6.00	20.00
Hand tools	9.00	150.00
Plows	6.00	30.00
Tar kettle	12.00	10.00
Concrete mixer	120.00	—
Brick roller	108.00	100.00
Wheel scrapers	5.00	15.00
Slush scrapers	—	—
Roller used for hauling	162.00	270.00
Hauling engine	132.00	300.00

Charge for bond ¼% total contract.

PLANT FOR WATERBOUND MACADAM IMPORTED STONE

Elevator unloading plant, provided more than 2,000 cu. yds. of stone is to be unloaded.

ITEM	Interest	Depreciation	Repairs
Elevator	$12.00	$30.00	$50.00
Bin	30.00	40.00	50.00
5 H.P. gasoline engine	15.00	30.00	50.00
1 roller with broom and sprinkling attachment	162.00	135.00	70.00
6000 ft. 1½" pipe	36.00	60.00	10.00
Gasoline engine and pump	12.00	40.00	50.00
Hand tools	9.00	150.00	—
Plows	6.00	30.00	—
Road machine	12.00	40.00	10.00
2 wheel scrapers	5.00	15.00	10.00
2 slush scrapers	—	—	—
15 wagons	80.00	300.00	150.00
Totals one season's work 5 miles	$379.00	$870.00	$450.00
Total per mile	76.00	174.00	90.00

Force account money out: Allow six weeks out continually for length of job at $\frac{1}{2}$% interest per month.

Allow $6,000 out, or $40.00 interest per mile on force account.

Bond charge: $\frac{1}{4}$ of 1% contract price; approximately $25.00 per mile. Insurance charge: $2.00 per $100.00 total force account, approximately $100.00 per mile.

Allow for moving plant on job, $500.00 lump sum.

Plant for Waterbound Macadam Local Stone

Item	Interest	Depreciation	Repairs
1 traction engine	$ 72.00	$150.00	$100.00
1 crusher and bin	100.00	220.00	400.00
1 steam drill and bits	10.00	50.00	80.00
1 small boiler for drill	12.00	30.00	20.00
Roller, pipe, gasoline engine and pump, hand tools, plows, road machine, scrapers and wagons as for imported stone plant. Total of these items	322.00	770.00	300.00
Total for season, 5 miles	$516.00	$1220.00	$900.00
Total per mile	103.00	245.00	180.00

Force account slightly larger on local stone roads. Approximately $7,000.00 out.

Interest on force account .... $50.00 per mile
Bond charge .... 20.00 " "
Insurance .... 120.00 " "
Moving plant on job, $500.00 lump sum.

Plant for Bituminous Macadam Imported Stone

Item	Interest	Depreciation	Repairs
Elevator unloading plant	$60.00	$100.00	$150.00
2 rollers	320.00	270.00	140.00
3 tar kettles	36.00	—	30.00
Hand tools, plows, road machine, scrapers and wagons as for waterbound macadam. Total of these items	112.00	535.00	170.00
Total for season, 5 miles	$528.00	$905.00	$490.00
Total per mile	106.00	181.00	98.00

Interest on force account .... $40.00 per mile
Bond charge .... 30.00 " "
Insurance .... 100.00 " "
Moving plant on job, $500.00 lump sum.

PLANT FOR BITUMINOUS MACADAM LOCAL STONE

Item	Interest	Depreciation	Repairs
1 traction engine	$72.00	$150.00	$100.00
1 crusher outfit	100.00	220.00	400.00
1 steam drill and bits	10.00	50.00	80.00
1 portable boiler for drill	12.00	30.00	20.00
Rollers, hand tools, plows, road machine, scrapers, wagons, and tar kettles as for imported stone. Total of these items	468.00	805.00	340.00
Total for the season, 5 miles	$662.00	$1255.00	$940.00
Total per mile	132.00	251.00	188.00

Interest on force account ....$50.00 per mile
Bond charge .... 25.00 " "
Insurance ....120.00 " "

Moving plant on job, $500.00 lump sum.

FORMS FOR ESTIMATES

The following forms of estimate have proved very satisfactory. The item of 6% on materials is used to cover demurrage and interest on money tied up on freight and stone. The other items of profit are what we consider a reasonable return for the risk of such contract work. Mechanical hauling is not considered, because few contractors own plants that make it possible. The total item of interest, depreciation, repairs, and interest on force account money for the whole job is charged against top and bottom stone, as the construction quantities of the macadam will vary less from the estimated quantities than any other classes of work.

Standard Estimates. Figured on the basis of 20% profit on labor, 6% on materials, 6% on money invested, and an allowance made for depreciation on different plants, as previously given.

Labor at $0.175 per hour
Teams at $0.450 " "

Earth Excavation.

Class	Amount per Mile	Price per Cu. Yd.
Easy	5,000–10,000 cu. yds.	$0.40
Easy	3,000– 5,000 cu. yds.	0.45
Easy	1,500– 3,000 " "	0.50
Average	3,000– 5,000 " "	0.50
Average	1,500– 3,000 " "	0.60
Hard...........	3,000– 5,000 " "	0.60
Hard...........	1,500– 3,000 " "	0.70

Rock Excavation.

Large boulders (for which 10 cu. yds. a mile are allowed on all estimates) . . .$1.50 per cu. yd.

1. { Steam drillwork, limestone .... 1.25 " " "
   " " " granite .... 1.50 " " "

2. { Hand " " limestone .... 2.00 " " "
   " " " granite .... 2.00 " " "

1. Large quantities
2. Small quantities

Field Stone Sub-base.

A sub-base course 6 in. deep made of the usual size fence stone requires 1 cu. yd. loose for 1 cu. yd. rolled; 12 in. deep requires 1.25 cu. yds. loose.

Cost of cobbles per loose cu. yd.	$0.10	Multiply these items by 1.25 for 12-in. depth of sub-base.
Loading cobbles per loose cu. yd......	0.15	
Hauling cobbles 1 mile per loose cu. yd.	0.35	
Placing cobbles per loose cu. yd.	0.10	
Rolling cobbles per loose cu. yd.	0.05	
Filler (see below)..................	—	
Total	$ —	
20% profit	$ —	
Estimate	$ —	

Filler.

$\frac{1}{3}$ cu. yd. per cu. yd. rolled sub-base.

Cost $\frac{1}{3}$ cu. yd. at pit or crusher	$ —
Loading $\frac{1}{3}$ cu. yd.	0.05
Hauling $\frac{1}{3}$ cu. yd. 1 mile	0.10
Spreading $\frac{1}{3}$ cu. yd.	0.04
Total	$ —

Sub-base Bottom Course.

Same relation of loose and rolled quantities as for sub-base.

Cost fence stone per loose cu. yd.	$0.10
Loading fence stone per loose cu. yd.	0.15
Hauling 1 mile per loose cu. yd.	0.35
Placing and sledging	0.20
Rolling	0.05
Filler (see below)	—
Total	$ —
20% profit	—
Estimate	—

Filler.

$\frac{1}{3}$ cu. yd. per cu. yd. rolled sub-base.

Cost $\frac{1}{3}$ cu. yd. at pit or crusher	$ —
Loading	0.05
Hauling 0.33 cu. yd. filler per mile	0.10
Spreading and brooming	0.08
Total	$ —

Imported Bottom Stone Materials.

3" course, 3,050[1] lbs. f.o.b. crusher	$—
4" " 3,150 " " "	—
6% profit	—
Total	$ —
Freight on stone to delivery point	—
Total, No. 1	$—

Labor.

Unloading		
Under 2,000 cu. yds. (shoveling)	$0.15	per cu. yd.
Over 2,000 cu. yds. (elevator)	0.10	" " "
Hauling (Teams)		
Bad conditions	0.35	" " "
Average conditions	0.30	" " "
Good conditions	0.25	" " "
Mechanical hauling	0.15	" " "
Spreading		
$5\frac{1}{3}$ in. loose depth	0.06	" " "
4 in. loose depth	0.08	" " "
Rolling	0.05	" " "

At this point total up and add 30% of the total to change the estimate from loose to rolled measure.

Filler (see below)	
Labor, total	$ —
20% profit	—
Total, No. 2	$ —

[1] These weights are for limestone. See pages 268, 272.

Filler.

Cost of 0.35 cu. yd. at pit or crusher	$ —
Loading 0.35 " "	0.05
Hauling 0.35 " " 1 mile @ $0.35 per yd. mile	0.12
Spreading and brooming 0.35 cu. yd.	0.07
Filler, Total	$ —

Summary.

Total No. 1	$ —
Total No. 2	$ —
Interest and depreciation	$ —
Estimate	$ —

Imported Top Stone Waterbound Macadam Materials.

[1] 4,450 lbs. stone f.o.b.	$ —
6% profit	$ —
Total	$ —
Freight on stone to delivery point	$ —
Total No. 1	$ —

Labor.

Unloading (same as bottom)	$ —
Hauling (same as bottom)	$ —
Spreading	0.08
Rolling	0.04
Puddling	0.06
Total, loose measure	$ —
Add 30%	$ —
Total rolled measure	$ —
Screenings. (See below)	
Total	$ —
20% profit	—
Total No. 2	$ —

Screenings.

[2] Unloading 0.5 cu. yd.	$0.07
Hauling 0.5 " " 1 mile	0.15
Spreading 0.5 " " by cross dump wagons	0.03
" 0.5 " " " hand	0.07
Total	$ —

Summary.

Total No. 1	$ —
Total No. 2	—
Interest, depreciation, etc.	—
Estimate	$ —

[1] These weights are for limestone. See pages 268, 272.
[2] Screenings are usually unloaded by hand.

IMPORTED TOP STONE BITUMINOUS MACADAM. PENETRATION METHOD

Materials.

2″ course, 4,350 lbs. stone and screenings, f.o.b. crusher ..	$ —
3″ " 4,050 " " " " " " ...	—
gal. bituminous binder, f.o.b. plant	—
6% profit	—
Total	$ —
Freight on materials to delivery point....................	—
Total No. 1	$ —

Labor.

No. 3 stone.

Unloading 1 cu. yd. (same as given)	$ —
Hauling 1 cu. yd. " " "	—
Spreading 1 cu. yd. " " "	—
Rolling 1 cu. yd.	0.09
Total	$ —
Add 20% for 2″ course, 30% for 3″ course	—
Total No. 2	$ —

No. 1A, No. 2, and Bitumen.

Unloading 0.6 cu. yd. for 2″ course (same as given)	$ —
" 0.45 " " " 3″ " " " "	—
Hauling at the rate of $0.30 per yd. per mile.............	—
Hauling bitumen at rate of $0.002 per gal. per mile	—
Spreading and brooming No. 1A and No. 2 at rate of $0.30 per cu. yd.	—
Manipulation of heating and spreading bitumen at $0.015 per gal..	—
Total No. 3	$ —
Total No. 2	—
Total	$ —
Add 20% profit	—
Total No. 4	$ —

Summary.

Total No. 1	$ —
Total No. 4	—
Interest, depreciation, etc.	—
Estimate	$ —

Local Stone Macadam.

Field stone.

1 cu. yd. field stone = 1 cu. yd. crushed.

1.8 cu. yds. field stone = 1 cu. yd. No. 3 and No. 4 rolled.

Cost of field stone	$0.10 per cu. yd.
Blasting or sledging, per cu. yd. actually blasted or sledged	0.40 " " "

Loading field stone	0.15	per cu. yd.
Hauling field stone 1 mile	0.35	" " "
Crushing		" " "
Sandstone (soft)	0.10	" " "
Limestone	0.15	" " "
Granite and trap rock	0.20	" " "
Total cost in bins (loose including Nos. 1, 2, 3, and 4 stone)	$ —	" " "

Quarried Stone.

Limestone, quarrying, small quarries	$0.50	" " "
Conglomerate, " " "	0.75	" " "
Trap, " " "	0.65	" " "
Crushing (same as above)	—	" " "
Total cost in bins	$ —	" " "

The crushing does not include repairs to crusher.
The crushing is taken from previously given data.
The item of quarrying includes delivery to crusher.

Estimate of Bottom Stone.

Cost in bins	$ —
Loading, per cu. yd.	0.01
Haul (same as bottom)	—
Spread (same as bottom)	—
Rolling (same as bottom)	—
Total (loose measure)	$ —
Add 30%	—
Total rolled measure	$ —
Filler (same as bottom)	—
20% profit	—
Total, No. 1	$ —
Interest and depreciation	—
Estimate	$ —

Local Top Stone.

Cost in bins	$ —
Manipulation same as for imported stone	—
Total	$ —
20% profit	—
Total No. 1	$ —
Interest and depreciation	—
Estimate	$ —

Imported No. 2 Stone, Estimated Loose

Material.

2,400 lbs. stone	$ —
6% profit	—
Total No. 1	$ —

Unloading (same as bottom)	—
Haul (same as bottom)	—
Spreading	0.10
Total	$ —
20% profit	—
Total No. 2	$ —

Total No. 1	$	—
Total No. 2		—
Estimate	$	—

Local No. 2 Stone.

Cost per cu. yd. in bins	$	—
Haul same as above		—
Spreading same as above		—
Total	$	—
20% profit		—
Estimate	$	—

The following is an example of the method of using these standard forms.

ESTIMATE FOR LOCAL FENCE STONE BOTTOM COURSE

Assume that stone will cost $0.10 per cu. yd. in the fences.
" ½ mile average haul to crusher.
" 20% of the stone has to be sledged or blasted.
" ¾ of a mile average haul from the crusher.
" that filler costs $0.15 per cu. yd. in the pit.
" average haul of ¼ mile for filler.
" that the interest and depreciation charge for the total job, say 4 miles, is distributed over 6,000 cu. yds. of macadam.

Use Standard form for Local Bottom Stone, given on page 261.

Cost 1 cu. yd. field stone	$0.10
Blasting and sledging ⅕ cu. yd. stone	0.08
Loading 1 cu. yd. field stone	0.15
Hauling 1 cu. yd. field stone ½ mile	0.18
Crushing 1 cu. yd. (Mixed granite and sandstone)	0.15
1 cu. yd. Total cost in bin	$0.66

Cost 1 cu. yd. crushed stone in bins	$0.66
Loading on wagons	0.01
Haul to road, average conditions, ¾ of a mile	0.22
Spreading 5⅓″ loose	0.06
Rolling	0.05
Total	$1.00

Add 30%	.30
Per. cu. yd. rolled measure	$1.30
Filler (see below)	0.31
Labor, total	$1.61
Add 20% profit	0.32
Total, No. 1	$1.93
Interest, depreciation, etc. (see below)	.56
Estimate per cu. yd. rolled in place	$2.49

say $2.50.

Filler. As mentioned on page 240, the screenings produced in crushing bottom only, as in this case, will amount only to 50% of the required filler, therefore two estimates must be made for filler as below:

Screenings for Filler.

Cost of 0.35 cu. yds. screenings in bin @ $0.66 per cu. yd.	$0.230
Loading 0.35 " " " from bin	0.003
Hauling 0.35 " " " ¾ of a mile	0.077
Spreading and brooming 0.35 cu. yds.	0.070
Total	$0.380

Sand Filler.

Cost of sand in pit 0.35 cu. yds.	$ 0.052
Loading 0.35 cu. yds.	0.050
Hauling 0.35 " " ¼ mile (short-haul figures)	0.060
Spreading and brooming 0.35 cu. yds.	0.070
Total	$0.232

Average these costs as the screenings must be utilized to use up the total output of the crusher. Average filler $0.31.

Interest, Depreciation, etc.

From page 255, using value adopted for, say, waterbound macadam roads, the following charge for a 4-mile road is figured:

Interest on plant	4×103.00	$412.00
Depreciation on plant	4×245.00	980.00
Repairs on plant	4×180.00	720.00
Interest on pay-roll	4× 50.00	200.00
Bond charge	4× 20.00	80.00
Insurance	4×120.00	480.00
Moving plant on job		500.00
Total		$3,372.00

to be spread over 6,000 cu. yds. of macadam.

$$\frac{3{,}372}{6.000} = 0.56 \text{ cents}$$

The cost of an improved highway generally depends on the item of top and bottom stone in place complete. Many of the minor items have standard prices. Such items as cast-iron pipe, the various sizes of tile, pipe railing, mesh reinforcement steel, etc., will hardly vary in price throughout the Eastern States. A table of these standard prices as used by the New York State Highway Commission is given below.

It will be noted that all of these items have little bearing on the total cost, and that the items of Earth Excavation, Sub-base, or Sub-base Bottom Course, Macadam Bottom and Top Course, Concrete Foundation, Brick Pavement, etc., which of necessity are not standard in price, determine whether or not the road is to be expensive.

Unit Prices Minor Items

Overhaul on excavation	$ 0.01	per yd. sta.
Third-class masonry cement joints	6.00	per cu. yd.
Second-class concrete	9.00	" " "
Third-class concrete (stone)	7.00	" " "
" " " (gravel)	5.50	" " "
Pointing old masonry	0.75	" sq. "
Riprap	1.50	" cu. "
Paving cement joints	1.50	" sq. "
Cobble gutter	0.50	" " "
Expanded metal	0.08	" " ft.
Guard-rail	0.30	" lin. ft.
2″ pipe rail	1.50	" " "
Concrete guard-rail	1.00	" " "
Cast-iron pipe in place	35.00	" ton
6″ V. T. P. in place	0.30	" lin. ft.
12″ V. T. P. " "	0.60	" " "
15″ V. T. P. " "	0.90	" " "
18″ V. T. P. " "	1.10	" " "
24″ V. T. P. " "	2.00	" " "
Relaying old pipe	0.10	" " "
4″ farm tile under drain in place	0.10	" " "
Steel in place	0.05	" lb.
Oak timber in place	50.00	" M.B.M.
Hemlock timber in place	40.00	" M.B.M.
Danger signs	2.00	each
Guide-board posts	6.00	"
Highway No. signs	1.00	"
Guide signs per letter	0.15	"

The item of Earth Excavation as shown in Table 36 may vary between 40c and 65c. In extreme cases where material is difficult to handle, it may be estimated still higher. A particular instance of costly excavation where 70c was estimated occurs on a road near the Lackawanna Steel Plant at Buffalo. This road had been filled with slag from time to time.

In the remaining variable items the length of haul is a governing factor and three actual conditions of determining the average haul are given here before proceeding farther with the estimate data.

The following cases 1, 2, and 3 show also the present method of estimating where interest and depreciation are not directly considered.

Case I

The simplest possible conditions. Perry Village County Highway, Wyoming County, N.Y. Imported stone, delivery at middle of road — coal trestle available for unloading — no dead haul to road. Road 16 feet wide throughout.

Railroad at Station 60 Station 0+00 = beginning of contract
106+23 = end of contract

For ease of computation, say stone runs 10 yds. to mile.

Station 0 + 00 to 60

1.1 miles average .55 miles .55 miles × 11 yds. = 6.05 yd. miles

Station 60 + 00 to 106 + 23

.87 miles average .44 miles .44 miles × 8.7 yds. = 3.83 yd. miles

Total yds. 19.7 9.88 yd. miles Total

$$\frac{9.88 \text{ yd. miles}}{19.7 \text{ yds.}} = 0.50 \text{ miles average haul}$$

Completion of Perry Village Estimate.

Stone from Rock Glen Quarries Stone $0.65 per ton f.o.b.

Cu. yd = 2400 lbs. Freight .40 " " "

Sub-base Stone .50 " " "

	Bottom		Top	Screenings		Sub-base
Stone	.78		.78	.78		.60
Unloading	.15		.15	.15		.15
Average haul ½ mi. at .35	.175		.175	.175		.175
Manipulation	.30		.25	.20		.20
				1.305		
Consolidation (plus ⅓).	.468		.451	.4	+ ⅕	.22
				.5220		
Filler (½ cu. yd. sand at $1.00)	.50	Screen-ings	.522	Sand		.50
Profit (20%)	.474		.465			.369
Freight (40 + .08 + .16)	.64	(40+.08+ .16+192)	.832	(40+08 +.096)		.576
6% interest on freight to cover demurrage, etc.	.038		.05			.034
Manipulation of Bituminous Material..			.60			
	$3.525		$4.275			$2.824
	Use $3.55		Use $4.30			Use $2.80

Case II

The Walker-Lake Ontario Road, Monroe County, N.Y. Road extends from Station 0 + 00 to Station 197 + 45.

Local stone — mostly fences. Because of location of stone as determined by engineer's inspection, it was determined to make three set-ups of crusher, at Station 40, 104 + 50 and at Station 157.

The hauls from stone piles to these crushing points were figured in the regular manner. From the crusher to road, the hauls were arranged,

From Station 40 — haul stone		0 + 00 to 77 + 00
" " 104 + 50 haul stone		77 + 00 " 130 + 00
" " 157	" "	130 + 00 " 197 + 45

Care was taken to see that enough stone was available near each crushing point to furnish macadam between stations supplied from that set-up.

The widths of road were as follows:

0 + 00 to 40 + 00 — 12′ wide
40 + 00 " 66 + 60 — 16′ wide
66 + 60 " 129 + 50 — 14′ "
129 + 50 " 197 + 45 — 12′ "

Use 10 yds. per mile for 12′ road
proportionally 11.7 yds. mile for 14′ road
" 13.3 " " " 16′ "

Haul on road from Station 40 + 00

12′ wide 0 + 00 to 40 + 00
0.76 miles average .38 .38 miles × 7.6 yds. = 2.89 yd. miles
16′ wide 40 + 00 to 66 + 60
.50 miles average .25 .25 miles × 6.6 yds. = 1.65 yd. miles
14′ wide 66 + 60 to 77 + 00
.20 miles average .1
plus dead haul .5
.6 .6 miles × 2.3 yds. = 1.38
16.5 5.92 yd. miles

Haul on road from Station 104 + 50

14′ wide Station 77 + 00 to 129 + 50 (say 130)
77 + 00 to 104 + 50
.52 miles average .26 .26 miles × 6.1 yds. = 1.59 yd. miles
104 + 50 to 130
.48 miles average .24 .24 miles × 5.6 yds. = 1.34 yd. miles
11.7 yds. 2.93 yd. miles

Haul on road from Station 157

12′ wide Station 129 + 50 (say 130) to 197 + 45
130 to 157
.51 miles average .26 .26 miles × 5.1 yds. = 1.33 yd. miles
157 to 197 + 45
.76 miles average .38 .38 miles × 7.6 yds. = 2.89 yd. miles
12.7 yds. 4.22 yd. miles

Average haul for entire road

From Station	40	16.5 yds.	5.92 yd. miles
" "	104 + 50	11.7 "	2.93 " "
" "	157	12.7 "	4.22 " "
		40.9	13.07

13.07 ÷ 40.9 = .32 miles
say .3 miles average haul

Sub-base Bottom Course

Stone	$ .15
Sledging, blasting, and sorting 30% of stone at .35 per yd.	.105
Loading into wagons	.15
Haul to crusher at Stations 40, 104 + 50 and 157. One mile at .35	.35
Haul on road. 3 mile at .35	.105
Manipulation	.20
Consolidation (plus $\frac{1}{5}$)	.212
Filler ($\frac{1}{2}$ cu. yd. sand at .80)	.40
Profit (20%)	.334
	$2.006

Use $2.00

Local Stone Top Course — Bituminous Binder

	Top Course	Screenings
Stone	.15	.15
Sledging, blasting, and sorting 60% of stone at .35	.21	.21
Loading into wagons	.15	15
Haul to Crusher at Stations 40, 104 + 50 and 157. 1.1 miles at .35	.385	.385
Crushing	.35	.35
Haul on road .30 miles at .35	.105	.105
Manipulation	.20	.20
Consolidation (plus $\frac{1}{3}$)	.517	1.55
		× .4
Filler (.4 cu. yd. of screenings)	.620	.620
Profit (20 %)	.537	
Manipulation Bituminous Material	.60	
	$3.824	

Use $3.85

Case III

The Obi-Cuba Highway, #965, Allegany County, N. Y. 9.93 miles long.

From a field inspection of this road, it was found that stone was available at both ends of road, but not in the middle. An ample supply of good gravel was found in the middle section, and it was determined to build a concrete base with bituminous top, this type of road being the only one which could be built using local material.

The hauls and freight charges on imported material would make the cost prohibitive.

The road was divided into three sections as follows:

Station	0 + 00 to 330	local field stone	concrete
Station	330 + 00 " 460	" gravel	"
Station	460 + 00 " 524 + 14	" quarry stone	"

Haul on stone 0 + 00 to 330. Crusher at 146, 220, and 285. These crusher set-ups were determined upon more by reason of nearness of stone supply and grade of haul than to equalize the hauling distance. The haul to the crusher was figured for the separate sources of supply and found to average $1\frac{1}{2}$ miles.

Haul from crusher on road, Station 146 to Station 0 + 00

(12′ wide use 10 yds. per mile) 2.76 miles, average 1.38 miles.

Station 146 to 170	1.38	miles	× 27.6	yds.	= 38.09	yd.	mi.
0.5 miles, average .25 miles	.25	"	× 5	"	= 1.25	"	"
Station 220 to 170							
1.0 miles, average 0.5 miles	.5	"	× 10	"	= 5.0	"	"
Station 220 to 245							
0.5 miles, average .25 miles	.25	"	× 5	"	= 1.25	"	"
Station 285 to 245							
0.8 miles, average 0.4 miles	.4	"	× 8	"	= 3.2	"	"
Station 285 to 330							
0.86 miles, average .43 miles	.43	"	× 8.6	"	= 3.7	"	"
Total for 1st section			64.2	yds.	52.49	yd.	mi.

$52.49 \div 64.2 = 0.82$ mile, average haul for 1st section.

Haul from gravel pit to road. Station 330 to 460.

Bank station 385 at side of road — no dead haul great enough to be figured.

Station 385 to 330					
1.1 miles, average haul .55 miles	.55 miles	× 11 yds.	= 6.05	yd.	miles
Station 385 to 460					
1.4 miles average haul .7 miles	.7 "	× 14 "	= 9.8	"	"
	Total	25 yds.	15.85	yd.	miles

$15.85 \div 25 = .63$ miles — Say .65 average haul

Haul from quarry in Village of Cuba $\frac{3}{4}$ mile from end of road.

Station 460 to 524 + 14

Station 460 " 500	14′ wide (use 11.7 yds. per mile)
Station 500 " 524 + 14	16′ wide (use 13.3 yds. per mile)

Station 460 to 500

0.8 miles, average	.4	mi.
Station 524 + 14 to 500 dead haul	.5	"
Quarry to 524 + 14 " "	.75	"
	1.65	"

1.65 miles × 9.36 yds. = 15.44 yd. mi.

Station 500 to 524 + 14			
0.5 miles, average haul	.25 mile		
Quarry to 524+14 dead haul	.75 mi.	1 mile × 13.3 yds. =	13.3 yd. mi.
	1.00 mi.	Total 22.66	28.74 " "

28.74 ÷ 22.66 = 1.27 Say 1.3 miles average haul

Haul on Sand *Pits at Stations 26 and 385*

Station 26 to 0 + 00				
.5 miles, average	.25 mi.	.25 miles	× 5 yds. =	1.25 yd. mi.
Station 26 to 330				
5.76 miles, average	2.88 mi.	2.88 "	× 57.6 " =	165.89 " "
Station 385 to 330				
1.04 miles, average	.52 mi.	.52 "	× 10.4 " =	5.4 " "
Station 385 to 460				
1.4 miles, average	.7 mi.	.7 "	× 14.0 " =	9.8 " "
Station 460 to 500				
0.8 miles, average	.4 mi.			
385 to 460 dead haul	1.4 mi.			
Total	1.8 "	1.8 "	× 9.36 " =	16.8 " "
Station 500 to 524 + 14				
0.5 miles, average	.25 mi.			
460 to 500 dead haul	.8 mi.			
385 to 460 " "	1.4 mi.			
Total	2.45 mi.	2.45 "	× 6.65 yds. =	16.3 " "
			103.01	215.44

215.44 ÷ 103.01 = 2.1 miles average haul.

Haul on Cement

Cement delivered at Cuba and Portville.

Station 0 + 00 to 160		Say 10 bbls. to mile
3 miles, average	1.5 mi.	7.5 miles × 30 bbls. = 225 bbl. mi.
dead haul, Portville	6.0 mi.	
to 0 + 00	7.5 mi.	
Station 160 to 460		
5.68 miles, average	2.84 mi.	
460 to 524 + 14 dead	1.3 mi.	
Penn. R.R. to 524 + 14	.2 mi.	
	4.34 mi.	
		4.34 mi. × 56.8 bbls. = 246.5 bbl. mi.
Station 460 to 500.		
.8 miles, average	0.4 mi.	
500 to 524 + 14 dead	.5 mi.	
Penn. R.R. to 524 + 14	.2 mi.	
	1.1 mi.	
		1.1 mi. × 9.36 bbls. = 10.3 bbl. mi.
Station 500 to 524 + 14		
.5 average	.25 mi.	
Penn. R.R. to 524 + 14	.2 mi.	.45 mi. × 6.65 bbls. = 3.0 bbl. mi.
	.45	102.81 — 484.8 bbl. mi.

484.8 ÷ 102.81 = 4.7 miles, average haul.

Having the haul figured for stone, gravel, cement, and sand, it was decided to obtain a composite price for the aggregate of the concrete instead of presenting an estimate with three prices for concrete foundation. This was done as follows:

Field Stone.

Stone	$.10 yd. royalty	
Blasting	.35 "	
Loading	.15 "	
Haul to crusher 1.5 @ 40c ..	.60 "	40c. yd mile used as haul
[1] Crushing	.30 "	was off steep hills and
Haul to road .8 mi. @ 35c...	.28 "	hard grades
	$1.78 yd.	

Gravel.

Gravel (royalty)	$.50
Stripping	.05
Loading (by hand)	.15
Haul to Station 385, 0.1 mile @ 35c..........	.03
Haul on road, .65 miles @ 35c.	.23
	$.96

Stone at Cuba Quarry.

This stone bought from quarry owner at flat rate of 75c. in bins:

Stone	$.75	
Haul 1.3 @ 35c..............................	.455	
	$1.205	Say $1.21

Sta. 0+00 to 330	= 6.25 miles	@ 10 yds.	= 62.5	× $1.78	=	$111.25
330 " 460	= 2.46 "	" 10 "	= 24.6	× .96	=	23.62
460 " 500	= .8 "	" 11.7 "	= 9.36	× 1.21	=	11.33
500 to 524+14	= .5 "	" 13.3 "	= 6.65	× 1 21	=	8.05
			103.11			$154.25

$154.25 ÷ 103.11 = $1.49 composite price

Sand

Sand (screened)	$1.00 yd. royalty	
Loading	.10 "	
Haul to road 0.1 @ 40c.........	.04 "	40c. used because of
Haul on road 2.1 miles @ 35c...	.735	steep hard grade
	$1.875	Say $1.88

Cement

Delivered at Cuba or Portville	$1.05 per bbl.
Haul .188 tons × 4.7 miles × .29 per ton mile ...	.25 " "
	$1.30

Concrete

Inasmuch as gravel must be screened and sharp sand supplied, the proportions for stone concrete, ratio 1 — 2½ — 5, were used in place of standard gravel proportions. This is Fuller's rule for proportions of cement, stone, etc., for one cubic yard of concrete. A table of these ratios for different mixtures is found on page 248.

Stone	$1.49 × .92 =	$1.3708
Sand.................................	1.88 × .46 =	.8648
Cement	1.30 × 1.21 =	1.573
		$3.8086

[1] This item is higher than noted in the previously given cost data, as this estimate is made according to the N. Y. S. method, which does not consider interest and depreciation as a separate item.

Mixing	$ .40
Spreading	.20
Profit 20%	.8817
	$5.2903

Say $5.30 per cu. yd.

Note: — This method of estimating does not consider depreciation directly. See other method of estimating following.

The method of estimating the top course for a Concrete Bituminous Top road does not vary from an ordinary bituminous top course, except that under the present New York State specifications the course is figured for loose measure. Therefore the items for consolidation and filler would be omitted.

Brick Cost Data on Country Roads.

The cost of brick pavements on country roads differs somewhat from similar work on city streets. There is not much data available for this class of work, but through the courtesy of Mr. Wm. C. Perkins, First Assistant Engineer, New York State Department of Highways, the author is able to give some unusually reliable data obtained from fifteen miles of brick paving averaging 14 ft. wide, built near Buffalo, N.Y., in 1910. Mr. Perkins' method of estimating, as given on page 331, assumes that 20% profit on both materials and labor will take care of the plant and pay-roll charges and give a reasonable profit. The method of estimating is different from that given on macadam roads. His results are good.

Excavation. Where brick pavement is built on an ordinary unimproved country road, the excavation is of the same class and will cost the same as given for macadam roads.

Where pavements are built over macadam roads and the old surface must be cut into two or three inches and reshaped, the excavation is much more expensive. For this class of work see page 335 (scarifying and reshaping).

Labor Manipulation for Different Items of Brick Pavement Laid During 1910, in the Buffalo Residency.

These items figured from force accounts kept by the different engineers in charge of roads.

Labor averaged $0.175 per hour.

Concrete Base, 5″ thick (exclusive of edging).

Machine-mixing, laying same in place, including labor of tamping, etc.

Road No. 2–R, Buffalo-Hamburg	$0.0853	per sq. yd.	
" " 128, Buffalo-Aurora	0.0991	" " "	(gravel concrete)
" " 863, Blasdell Village	0.1228	" " "	
" " 87, Main Street, Sec. 2.	0.1129	" " "	(3″ base)
" " 862, Hamburg Village	0.0655	" " "	(28′ and 30′ wide)

The excessive cost on Blasdell Village due to a poor concrete mixer (gasoline) which was constantly breaking down.

On Main Street, Sec. 2, poor organization and too high priced men; also, lack of water, causing delays.

On Hamburg Village low price due to width of base 28′ and 30′, allowing work to progress faster.

On Road No. 69, Main Street, Sec. 1, edging and base were laid in one operation; gasoline mixer; plenty of water; cement, $1.12; sand $1.40; labor, $1.90 per day; stone, $1.12 per cu. yd.; base 3″ thick; 8″ edgings; cost in place, including edging $4.696 per cu. yd., or $0.506 per sq. yd., or $0.886 per lin. ft. of road.

Assumption. If we assume, $0.09 per sq. yd. as an average cost for 16′ road (exclusive of edging) the manipulation would be $0.648 per cu. yd.

If we assume $0.0655 per sq. yd. for street work (Hamburg Village) the manipulation would be $0.472 per cu. yd.

Concrete Edging. 8″ thick.

Hand-mixed; placing same, including erecting of forms, and removing same; tamping, placing steel, and all labor necessary.

Road No. 2–R, Buffalo-Hamburg,	$0.0730	per lin. ft. of edging
	0.0821	" sq. yd. of pavement (Road 16′ wide)
Road No. 128, Buffalo-Aurora,	0.0555	" lin. ft. of 5″ edging
	0.0713	" sq. yd. pavement (Road 14′ wide)
Road No. 863, Blasdell Village,	0.0826	" lin. ft. edging
	0.0929	" sq. yd. pavement (Road 16′ wide)
Road No. 87, Main Street, Sec. 2,	0.0748	" lin. ft. edging
	0.0842	" sq. yd. pavement (Road 16′ wide)

On Road No. 862, Hamburg Village, concrete curb 6″ top, 10″ bottom, 15″ deep; hand-mixed, exposed curbing, all labor, including erection and removal of forms, $0.1294 per lin. ft.

Assumptions. If we assume $0.082 per sq. yd. of paving as cost of edging and $0.09 per sq. yd. cost of base, the total cost per sq. yd., 16′ road (including edging) would be $0.172 per sq. yd., or the manipulation would be $1.238 per cu. yd.

If we assume $0.073 per lin. ft. of 8″ edging 10½″ deep, the manipulation would be $3.379 per cu. yd. of the edging in place. (This high cost due to forms, etc., and the small amount of concrete per lin. ft.)

Sand Cushion.

Spreading sand, rolling, and making bed ready for work.

Road No. 2–R,	Buffalo-Hamburg,	$ 0.0102	per sq. yd.
Road No. 128,	Buffalo-Aurora,	0.0082	" " "
Road No. 863,	Blasdell Village,	0.0187	" " "
Road No. 87,	Main St., Sec. 2,	0.0151	" " "
Road No. 862,	Hamburg Village,	0.0160	" " " (28′ and 30′ wide)

On Main Street, Sec. 1, Road No. 69; sand, $1.40; labor, $1.90; cost per sq. yd. 2″ thick, $0.0838, including material.

Assumption. From the above I would assume $0.013 per sq. yd. as cost of preparing sand cushion.

Brick Pavement.

Laying brick, including all labor of handling from the piles, removing all culls, and the rolling of the brick.

Road No. 2–R, Buffalo-Hamburg,	$ 0.0611	per sq. yd.
Road No. 128, Buffalo-Aurora,	0.0544	per sq. yd.
Road No. 863, Blasdell Village,	0.0969	per sq. yd.
Road No. 87, Main St., Sec. 2,	0.0965	per sq. yd.
Road No. 862, Hamburg Village,	0.0700	per sq. yd. (28′ and 30′ wide)
Road No. 69, Main St., Sec. 1,	0.0983	per sq. yd.

Assumption.

I consider Blasdell and Main Street, Sec. 1 and Sec. 2, too high and the engineer claims that the force was cut up and wasted time.

I would assume $0.070 per sq. yd. as cost of laying brick, etc.

Grouting.

Necessary grouting to obtain flush joints, scoop method, including the placing of the protecting sand covering.

Road No. 2–R, Buffalo-Hamburg,	$0.0219	per sq. yd.
Road No. 128, Buffalo-Aurora,	0.0211	per sq. yd.
Road No. 863, Blasdell Village,	0.0322	per sq. yd.
Road No. 87, Main St., Sec. 2,	0.0321	per sq. yd.
Road No. 69, Main St., Sec. 1,	0.0285	per sq. yd.
Road No. 862, Hamburg Village,	0.0273	per sq. yd. (28 and 30′ wide)

On Main St., Sec. 1, Road No. 69; sand, $1.40; cement, $1.12; labor, $1.90; actual cost $0.0848 per sq. yd., including materials.

Assumption.

From the above I would assume $0.028 per sq. yd., as the cost of applying grout.

Expansion Joints.

Removing strips, cleaning joints, and pouring tar.

Road No. 2–R, Buffalo-Hamburg,	$0.0067	per lin. ft. of joint
	0.0076	per sq. yd. pavement (Road 16′ wide)
Road No. 128, Buffalo-Aurora,	$0.0057	per lin. ft. of joint
	0.0073	per sq. yd. pavement (Road 14′ wide)
Road No. 863, Blasdell Village,	$0.0115	per lin. ft. of joint
	0.0129	per sq. yd. pavement (Road 16′ wide)

On Main Street, Sec. 1, Road No. 69, the expansion joints cost $0.0296 per lin. ft., or $0.033 per sq. yd. (Road 16′ wide), including material, labor, etc.

Assumption.

From the above I would assume $0.0075 per sq. yd. as the cost of expansion joints.

Unloading.

Data for unloading not reliable.

Road No. 2–R Buffalo-Hamburg	$0.014 per sq. yd.
Road No. 863, Hamburg Village	Contract taken for $1.50 per 1,000 brick; unloaded, haul ½ mile, and pile; this would be $0.06 per sq. yd.
Road, No. 69, Main St., Sec. 1	$0.019 per sq. yd.

Assumption.

I would assume $0.028 per sq. yd. as on and off.

Hauling.

No reliable data.

If we allow 600 brick per load, $5 per day for teams, 10 loads per day, haul 1 mile costs $0.034 per sq. yd.

Summary, Labor Cost of Brick Pavement.

MANIPULATION OF CONCRETE

Pavement 16′ wide; edging 8″ × 10½″.

*Concrete base	$0.09 per sq. yd.	$0.648 per cu. yd.
" edge	0.082 " " "	3.378 " " "
Concrete base and edging	$0.172 " " "	1.238 " " "

BRICK WORK LABOR

Preparing sand cushion	$0.0130	per sq. yd.
Laying brick	0.0700	" " "
Grouting	0.0280	" " "
Expansion joints	0.0075	" " "
On and off	0.0280	" " "
Haul one mile	0.0340	" " "
Cost of labor	$0.1805	" " "

Useful Data for Brick Roads.

6″ × 10½″ edging per lin. ft. of edging	0.016203 cu. yd.
8″ × 10½″ " " " " "	0.021605 " "
5″ × 16′ concrete foundation per lin. ft. 16′ road	0.24691 " "
2″ sand cushion loose per sq. yd.	0.0555 " "

1 barrel of cement will grout 36 sq. yds. of pavement.
1 barrel of paving pitch will fill 130 lin. ft. of joints 1″ wide.

Amount of Grout Required for Stone Block Paving.

For blocks similar to Medina sandstone blocks, running about 26 to the sq. yd., Gillette states that 0.6 cu. ft. of joint filler are required per sq. yd. of pavement with joints averaging ½″ wide. Second quality blocks with wider joints require proportionally more.

* Recent cost data indicates that $0.35 per cu. yd. is ample.

STANDARD ESTIMATE, BRICK SURFACING, EXCLUSIVE OF FOUNDATION

Materials.

	Per Sq. Yd.
Cost of brick, f.o.b. unloading point	$
" " sand for sand cushion, on job	
" " " " grout, on job	
" " cement for grout, on job	
" " paving pitch for expansion joints, on job	

Labor and Teaming.

Unloading brick and piling along road	$0.035
Hauling brick per mile	0.040
Preparing sand cushion	0.020
Laying brick	0.070
Grouting	0.028
Expansion joints	0.007
Total	$ —
Add 20% profit	—
Estimate	$ —

SAMPLE — STANDARD ESTIMATE, BRICK PAVEMENT — WM. C. PERKINS

Brick: $22.50 per 1,000 f.o.b. cars at Road siding, bricks lay 40 to the sq. yd.
Labor, $0.175 per hour, 10 hours.
Sand, 1.00 per cu. yd. on cars at siding.
Stone, 1.25 per cu. yd. on cars at siding.
Cement, 1.30 per bbl. delivered on work.

Sand:

f.o.b. cars	$1.00
Unloading	.15
Haul 1 mile @ $0.30	.30
Cost cu. yd. sand	$1.45

Stone:

f.o.b. cars	$1.25
Unloading	.15
Haul 1 mile @ $0.30	.30
Cost cu. yd. stone	$1.70

Concrete: 1 – 2½ – 5.

Use any standard mixing tables, stone 1″ and under, dust screened out.

Cement, 1.19 bbls.	× $1.30 =	$1.55
Sand, 0.46 cu. yds.	× 1.45 =	0.67
Stone, 0.91 " "	× 1.70 =	1.55
*Manipulation	=	0.50
		$4.27
20 % profit		.85
Total		$5.12

* Recent cost data indicates that $0.35 is ample with labor at $0.175 per hour.

The manipulation is based on machine-mixing and is for base alone laid 5″ thick. The concrete edging is estimated separately and runs from $0.13 to $0.15 per lin. ft.

Material per Square Yard

Brick f.o.b. cars	$0.900	
Sand cushion and cover	0.080	
Grout (sand and cement)	0.042	
Material expansion joint	0.008	
		$1.030
Labor per Square Yard		
Unloading and piling	$0.035	
Haul 1 mile	0.040	
Laying and rolling	0.070	
Making sand cushion	0.020	
Grouting	0.028	
Expansion joints	0.007	
Culling, replacing, etc	0.005	0.205
		$1.235
20% profit		.247
Total		$1.482

Therefore, standard 16′ road is estimated to cost, per square yard (exclusive of edging):

Concrete base	$0.711	
Brick	1.482	
Total	$2.193	per sq. yd.
Say,	$2.20	per sq. yd.

In the above estimate I have allowed 20% profit on material and freight. I do this so as to cover all interest charges, incidentals, contingencies, etc. I consider this one of the fairest ways to take care of all general expenses.

MAINTENANCE AND REPAIR COSTS

Cold Oiling. The following data is furnished by Mr. Frank Bristow, Supt. of Repairs, Division No. 5, New York State Department of Highways. The work was done in 1910. Labor averaged $0.20 per hour; teams, $0.50 per hour.

Oiling. Actual Cost Data. No. 6 stock or 65% asphaltic base oils applied cold by Studebaker Oiler upon macadam road which had been swept by horse sweeper, oil being broomed by hand where necessary and then covered by a thin coat of dustless screenings, or gravel, spread by hand.

The labor costs include pumping oil from the car tank, hauling same to road, applying same, sweeping road and spreading screenings; also, demurrage on cars and moving tools and repairs, but not cost of the plant.

TABLE 51

County	No. Jobs Average	Average Haul, Miles	Average cost of materials: Oil per Gal. on siding	Average cost of materials: Cover per Cu. Yd. Along Road	Average Quantities of Materials Used: Gallons per Sq. Yd.	Average Quantities of Materials Used: C. Y. Cover per Sq. Yd.	Average Cost: Labor per Sq. Yd.	Average Cost: Total Labor and Material per Sq. Yd.
Orleans	7	2.48	$0.0435	$1.82	0.42	0.016	$0.013	$0.057
Niagara	4	2.24	0.0425	1.57	0.43	0.016	0.014	0.057
Erie	12	2.00	0.0437	1.88	0.34	0.012	0.007	0.045
Erie	3	4.43	0.0455	1.83	0.42	0.015	0.019	0.066

Other information would show that cost per mile to sweep average road is $8.33; cost per gallon applying oil $0.0075; cost all labor sweeping, hauling, applying oil and cover about $0.25 per gal. used.

TABLE 51A

DIVISION 7 N. Y. S. DEPT. HIGHWAYS

H. G. HOTCHKISS SUPT. MAINTENANCE

Cost Data for Oiling, Surface Treatment 1915

Miles	No. Sq. Yds.	Kind Bit. Mat.	Gals. per Sq. Yd.	No. Tons of Cover per Mile	Total Cost per Sq. Yd.	Total Av. Cost per Sq. Yd.	Cost per Mile 16′ Surface
20.54	158144	C. O.	0.25	62	0.0344		
23.63	188208	C. O.	0.25	41	0.0250		
17.75	146734	C. O.	0.24	37	0.0237	0.026	244.06
19.94	172775	C. O.	0.19	43	0.0189		
21.47	200995	C. O.	0.19	59	0.0264		
16.22	199925	C. O.	0.28	74	0.0287		
22.51	188601	L. C. O.	0.20	31	0.0195	0.0183	171.78
41.09	382330	L. C. O.	0.20	27	0.0177		
15.44	126657	H. C. T.	0.25	40	0.0323	0.0330	309.77
13.42	126056	H. C. T.	0.25	40	0.0337		
17.19	143846	L. C T.	0.25	47	0.0319	0.0319	299.45

C. O. = Cold Oil. See Specifications, page 386.
L. C. O. = Light Cold Oil.
H. C. T. = High Carbon Tar. See Specifications, page 388.
L. C. T. = Low Carbon Tar. See Specifications, page 389.
Cover Material; Slag or Stone Screenings and Pea Gravel.
Cost of Applying Oil (Mechanical Spreaders).................... $0.01 per gal.
Cost of Applying Cover approx.................................. 0.25 " ton
Cost of Oils on Switch C. O. $0.03
L. C. O. 0.03
H. C. T. 0.07
L. C. T. 0.06

TABLE 51 B

DIVISION 7 N. Y. S. DEPT. HIGHWAYS
Cost Data Repainting and Rebuilding Guard Rail 1914

No. Lin. Ft. Painted One Coat	Cost per Lin. Ft.	No. Lin. Ft. Painted Two Coats	Cost per Lin. Ft.
15325	$.0212	26428	$.0425
79925	.0233	8433	.0360
17486	.0251	12824	.0352
42027	.0264	13160	.0442
Rebuilding Wooden Guard Rail		Rebuilding Concrete Guard Rail	
No. Lin. Ft.	Cost per Ft.	No. Lin. Ft.	Cost per Ft.
160	$.219	100	$0.896
554	.189	335	0.764
360	.200		
272	.141		

Hot Tar Flush Coats. The cost of applying hot tar flush coats by hand is practically the same as given for applying Bituminous Binder penetration method.

The writer has no reliable data on the cost of machine application.

Calcium Chloride. The cost of applying calcium chloride as a temporary dust layer on ten miles of road in Monroe County, N.Y., as given by Mr. Frank Bristow, First Assistant Engineer, New York State Department of Highways, is as follows:

The material was applied by an ordinary agricultural drill. The force used was, 1 horse and driver, $0.30 per hour; 1 helper, $0.20 per hour. No preliminary work of sweeping was done; the material was spread on the middle 12 feet of macadam, using approximately 0.75 lbs. to the sq. yd., the average speed being 0.5 miles, or 3,500 sq. yds., per day, at a cost of $0.0015 per sq. yd.

Cost of calcium chloride at plant.	$13.00	net ton
Freight.	1.60	per "
Unloading from cars, approximately. . .	0.15	" "
Hauling three miles, " . .	0.90	" "
Total, delivered on road. . . .	$15.65	" "
Total per sq. yd. delivered on road. . . .	0.0059	
Labor of spreading.	0.0015	
Total per sq. yd. in place. . .	$0.0074	
Total per mile 12′ wide, approximately.		$52.00

Cost of Applying Calcium Chloride

Road No. 5507 Scottsville — Canawagus. Season 1915. W. G. Harger, Eng. in charge.

15 tons were applied at the rate of $1\frac{1}{2}$ lbs. per sq. yd. on a 16′ road for $22.00 or at the rate of $1.50 per ton.

Force used, 1 team hauling agricultural plaster spreader. 2 laborers helping driver. Calcium Chloride in metal drums had been previously distributed along the road.

Wages: Team, $5.00 per day; Laborers, $2.00 per day.

Recapping The cost or recapping with any style of macadam is practically the same as original construction for that style of work except the item of scarifying and reshaping the old road.

Scarifying. The cost of scarifying, as given by Mr. E. A. Bonney on the Erie County repair work for the season of 1907, is as follows:

COST DATA ON RESHAPING ROAD

Work was done on Main Street Road, No. 69, Erie County, N.Y., between July 15 and Sept. 13, 1907.

The road had been built as a waterbound macadam. It was worn out, particularly in the center. There were few ruts, but the road was nearly level; in some stretches the center was lower than the sides. It was proposed to reshape the road and to lay a new top course treated with tarvia.

The work of reshaping was done by loosening the old surface with spiked wheels of roller; this separated the crust into chunks of various sizes which were broken up by men with picks. The stone was then raked from the sides to the center, brought to the required crown, and rolled ready for the new course of stone.

The cost of the complete operation included the number of men picking and the rollerman's salary.

Labor...............	$0.175 per hour
Rollerman...........	0.300 " "

The roller was rented at a flat rate of $5.00 per day, and a portion of the time it was used on other parts of the work. This cost plus the coal and oil is not included.

The data was compiled daily, and as the work was performed practically every working day between the dates named an average of the square yard price should be nearly correct. The highest cost on any one day was $0.06 per sq. yd., the lowest cost $0.016, and the general average $0.03 per sq. yd.

[1] Through the courtesy of Mr. Halbert P. Gillette, author of "Handbook of Cost Data," we are able to publish the following:

Cost of Resurfacing old Limestone Macadam. "In Engineering News, June 6, 1901, I gave the following data to show that the intermittent method of repairing macadam is the most economic.

[1] Gillette's Handbook of Cost Data, Myron C. Clark Publishing Company, edition of 1907, page 147. Pages 288 and 289, edition of 1910, in slightly different form.

The data were taken from my timebooks and can be relied upon as being well within the probable cost of similar work done by contract under a good foreman. It will be noted that the cost of operating the roller is estimated at $10.00 per day. This includes interest and depreciation as well as fuel and engineman's wages.

"The road was worn unevenly, but as it still had sufficient metal left, very little new metal was added.

"The roller used was a 12-ton Buffalo Pitts, provided with steel picks on the rear wheels. It required eighty hours of rolling with the picks in to break up the crust of a surface 19,400 sq. yds. in area, 240 sq. yds. being loosened per hour. The crust was exceedingly hard, and, at times, the picks rode the surface without sinking in, so that a lighter roller would probably have been far less efficient. In fact, a ten-ton roller had been used a few years previous for the same purpose at more than double the expense per square yard, I am told. The picks simply open up cracks in the crust of a depth of about four inches, and it is necessary to follow the roller with a gang of laborers using hand picks to complete the loosening process. The labor of loosening and spreading anew the metal was 1.880 man-hours, or a trifle more than 10 sq. yds., per man-hour. About 60% of this time was spent in picking and 40% in respreading with shovels and potato hooks.

"After the material had been respread, the short section was drenched with a sprinkling cart, water being put on in such abundance that when the roller came upon the metal the screenings which had settled at the bottom in the spreading process were floated up into the interstices. The roller and sprinkling cart were engaged only 63 hours in this process, 300 sq. yds. being rolled per hour; an exceptionally fast rate. The rapidity of rolling was due to four factors: 1. The great abundance of water used, the water being a very short haul. 2. The unyielding foundation (telford) beneath. 3. The abundance of screenings and fine dust, the road not having been swept for some time. 4. The great weight of the roller, which was run at a high rate of speed. I am not prepared to say that longer rolling woule not have secured a harder surface, but I doubt very much whether it would. The metal, I should add, was hard limestone. Summing up, we have the cost of resurfacing the road per square yard to have been as follows:

	Cents per sq. yd.
Picking with roller at $1 per hour	$0.40
Picking by hand labor at $0.20 per hour	1.20
Respreading by hand labor at $0.20 per hour	0.80
Rolling with roller at $1 per hour	0.33
Sprinkling with cart at $0.40 per hour	0.13
Foreman, 143 hours at $0.30 for 19,400 sq. yds.	0.44
Total	3.30

"At this rate a macadam road sixteen feet wide can be resurfaced for a little more than $300 per mile. The frequency with which such resurfacing is necessary will, of course, depend upon several factors,

chief of which are the amount of traffic and the quality of the road metal. I should say that five years would not be far from the average for a country road built of hard limestone. Unless the road has had an excess of metal used in its construction, new metal should be added at the time of resurfacing to replace that worn out.

"I am unable to see how any system of continuous repair with its puttering work here and there can be as economical as work done in the manner above described. I would not be understood, however, as favoring an entire neglect of the road between repair periods. At times of heavy rains and snows, ditches and culverts need attention and there should be some one whose duty it is to look after such matters. What I do question is the economy of having a man continuously at work putting in patches upon the road."

[1] NEW YORK STATE PATROL MAINTENANCE, 1910

The standard Patrol distance is five miles.

The standard Patrol distance, brick roads, is twelve miles.

Patrolman's wages $78 per month, including horse and cart. Patrol is operated eight and one-half months in a year.

The cost of this system of maintenance per mile for 1910 was, approximately, $250 exclusive of administration charges.

Patrolman's wages	$125.00
Materials	125.00
	$250.00

These costs do not include surface treatments. Such a treatment of a road every two years would amount to about $375 a mile per year on waterbound roads.

Automobile Truck Repair System. The tendency on minor repair maintenance work seems to be towards lengthening the patrol distance; confining the duties of the patrolman to cleaning culverts and ditches, trimming shoulders, and reporting the necessity of minor repairs. It is believed that these repairs can be handled more economically from a central point by the use of an automobile truck specially equipped for such work and which can operate within a radius of 20 to 30 miles. Special trucks have been devised with facilities for heating and applying bituminous materials as well as carrying materials.

Conclusion. In conclusion the author desires to again call the attention of the reader to the fact that while cost data is valuable it must be used with discretion and not figured too closely.

[1] Data obtained from Mr. Frank Bristow, Supt. of Repairs, N.Y.S. Dept. of Highways.

Table showing Character of Maintenance and Renewal Expenditure for 1914, over 500 Miles of Road

Div. No. 7

New York State Commission of Highways

Perry Filkins
Div. Engr.

Maintenance Department Report 1914

H. G. Hotchkiss, Jr.
Act. Supt. of Maint.

County	Miles	Resurfacing		Oiling		Patrol	Maint. Mat.	Extra Labor	Guard Rail	Miscel.	Eng. and Insp.	Total
		Miles	Cost	Miles	Cost							
Genesee..........	31.90	3.00	$9470.50	24.74	$6419.63	$2574.00	$310.86	$910.44	$451.55	$161.67	$2072.13	$22370.78
Ontario..........	100.99	5.59	40068.03	52.38	19399.66	7311.00	4167.60	7921.50	1713.78	286.96	3930.98	84799.51
Orleans..........	58.14	3.47	13482.82	36.02	15796.64	4629.00	2337.01	1388.86	460.34	94.26	4537.10	42726.03
Livingston	82.05			41.19	16392.56	6753.00	2044.05	557.83	1441.77	334.00	3550.66	31073.87
Monroe..........	220.19	4.75	68062.19	100.36	50682.88	14331.00	13317.54	9683.57	3702.02	986.57	9534.42	170300.19
Wyoming........	21.36			4.00	2423.60	1866.00	811.77	1573.51	581.85	70.73	1358.40	8685.86
Total...........	514.63	16.81	$131083.54	258.69	$111114.97	$37464.00	$22988.83	$22035.71	$8351.31	$1934.19	$24983.69	$359956.24

Average Cost per Mile Oiling $429.52 Engineering and Inspection 6.94%
" " " " Resurfacing 7797.95
The Items of Maint. Mat. and Extra Labor Monroe Co. Includes 5.75 Miles Calcium Chloride Ave. Cost per Mile $185.23
Average Cost per Mile Patrol 73.00
No. Ft. Guard Rail Painted One Coat 154763 Average Cost per Foot .0240
" " " " " Two Coats 60845 " " " " .0403
" " Wooden Guard Rail Rebuilt 1426 " " " " .19
" " Concrete " " " 2196 " " " " .85

CHAPTER XI

NOTES ON CONSTRUCTION

No matter how well a road is designed, unless the constructing engineer uses good judgment, and the inspection is conscientious and intelligent, the results will not be satisfactory. This chapter emphasizes the importance of the different stages of the work and gives a few suggestions as to the manner of meeting common difficulties.

Staking out for Construction. The construction survey picks up the center line shown on the plans and by means of offset stakes driven to a certain elevation marks the position and elevation of the road conveniently for building. Any arrangement of stakes that shows the position of the proposed center line and the elevation of the proposed grade is satisfactory. These stakes may be set on one or both sides of the road at intervals of 50 or 100 feet. The offsets to the center line may be marked to the nearest one-tenth foot, or the stakes may be so set that the offset is an even foot, and they may be driven so that the elevation of the proposed grade is above or below them an even foot, one-half foot, or an odd tenth. A satisfactory method in general use in western New York is to set the construction stakes on both sides every 50 feet, with an even foot offset and driven to such elevation that they are either an even foot or one-half foot above or below grade.

Staking Out								Notes				
Sta.	Offsets		Cut or Fill		Levels				Grade	Grade Rod Reading	Rod Reading on Stakes	
	L.	R.	L.	R.	B.S.	F.S.	Elev.	H.I.	Elev.		L.	R.
B.M.*5							526.42					
10	25	23	F0.5	F1.0	4.17			530.59	524.2	6.4	6.9	7.4
+50	25	22	F0.5	F1.5				"	524.6	6.0	6.5	7.5
11	24	25	F0.5	F1.5				"	525.0	5.6	6.1	7.1
+50	21	26	C0.5	F1.0				"	525.4	5.2	4.7	6.2
12	22	25	C0.5	F1.5				"	525.8	4.8	4.3	6.3
+50	23	24	C1.0	F2.0				"	526.2	4.4	3.4	6.4
13	24	24	Gr.	Gr				"	526.6	4.0	4.0	4.0
+50	25	23	Gr.	F0.5				"	527.0	3.6	3.6	4.1
14	30	17	Gr.	C0.5		3.20	527.39	"	527.8	2.8	2.8	2.3
+50	25	23	Gr	C1.0	7.41			534.80	528.6	6.2	6.2	5.2
15	25	23	C0.5	F1.5				"	529.4	5.4	4.9	6.9
+50	25	23	F1.0	F1.0				"	530.2	4.6	5.6	5.6
16	25	23	Gr.	C1.0				"	531.0	3.8	3.8	2.8
+50	25	23	F1.5	C1.0				"	531.8	3.0	4.5	2.0
17	24	24	F1.5	Gr.				"	532.6	2.2	3.7	2.2
+50	18	28	F1.0	F5.0				"	533.4	1.4	2.4	6.4
								"				

FIG. 67

Such stakes can be readily explained to the ordinary grading foreman so that he has no difficulty in working from them without the assistance of an inspector. The 50-foot interval is convenient for fine grading, as the lines can be stretched this distance with no apparent sag, while if a 100-foot interval is used the sag is objectionable. With stakes on both sides of the road the elevation of the proposed grade can be readily transferred to the center by stretching a line between them and measuring down or up the required amount. This is a much simpler and more accurate method than transferring by straight-edge where two or three lengths of straight-edge must be used from the stake to the center.

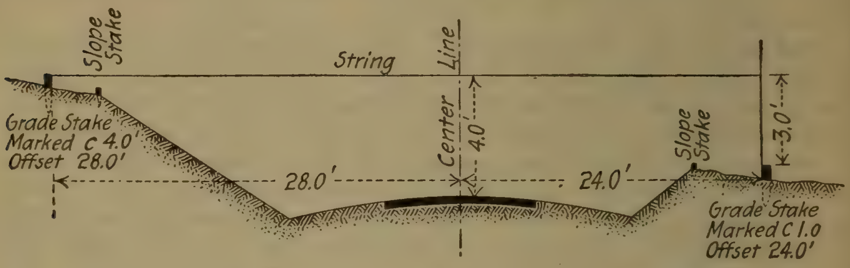


FIG. 68. — Showing Suggested Method of Staking out

The left stake marked C 4.0′ offset 28.0′ means that the crown grade of the finished road is 4.0 feet below the top of this stake and that the proposed center line of macadam is 28.0′ from the face of the stake.

To transfer the proposed grade to the center by the string method. Fasten chalk line to top of left stake; measure up 3.0′ above top of right stake and draw line taut at this elevation. The string is level and 4.0′ above crown grade. Pull as tight as possible, allow about ½″ for sag and measure down 3′ 11½″ for finished grade.

Cost of Staking Out. The speed and cost of staking at 50-foot intervals will, of course, vary with the experience of the men and the character of the road. A party of four men should pick up the proposed center line and set offset stakes on both sides at a speed of 1.5 to 2 miles a day; a party of three men should grade these stakes at a speed of 1.0 to 2.0 miles a day, and the cost of staking out for construction, including livery and board, would be from $20 to $30 per mile.

It is common for new men to spend an unnecessary amount of time in setting the grade stakes. They will often attempt to have the elevation of the grade stakes correct to within 0.01 foot. For all practical purposes, for work of this character, stakes correct to within 0.1 foot in elevation and 0.1 foot in alignment are satisfactory. Curb stakes for village work, however, should be carefully set to within 0.02 foot in elevation and line.

CONSTRUCTION

Rough Grading. By rough grading is meant all of the work preliminary to the finished shaping, and includes moving practically all the dirt that is to be handled. It is particularly important to supervise this stage of construction, as it is here that the constructing engineer regulates the placing of the best material in the center (under the metalling) and the poorer materials on the sides.

In order to grade economically, the contractor and inspector should each be furnished with lists similar to those given below, showing, in a convenient form, the amount of excavation station by station and within what bounds it is to be placed.

Excavation Summary

Sta. to Sta.		Exc.	Emb.	Waste	Borrow
123	134	476	375		
134	140	286	240		
140	157	642	662		185
157	178	766	629		
178	179	231		231	
179	186	298	244		

Detail Quantities

Sta. to Sta.		Exc.	Emb.
123	123+50	575	225
123+50	124	150	900
124	124+50	—	1450
124+50	125	150	900
125	125+50	320	200
125+50	126	170	500
126	126+50	30	925
126+50	127	30	850
127	127+50	260	410
127+50	128	350	250
128	128+50	635	160
128+50	129	635	75

Lists

Remarks
Quantities in cu. yds.
Haul from Sta. 179 to 150
Quantities in cu. ft.

Fig. 69

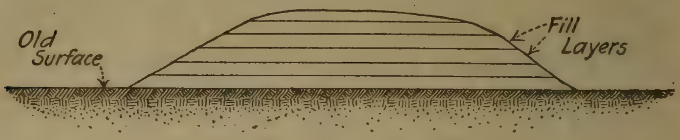
Cuts. For cuts over 3 feet deep slope stakes are placed and care taken that the slopes are properly carried down. If excavated beyond the finished lines it is practically impossible to make a back-fill that will hold and the resulting irregularities are unsightly.

Fills. For fills slope stakes are set in the same manner as for cuts.[1] The earth should be deposited in thin layers, six to eight inches deep, extending from slope to slope, and each layer well compacted either with a roller or by driving over it with wagons in the process of building. Where the old surface has a steep slope it must be plowed to give a good bond with the new fill and prevent slide.

It is bad practice to build the center of the fill and then shovel

[1] Slope stakes can be located directly from the templet Cross Sections which is a much easier method than the railroad practice of rod and level computation.

loose material off of the edge to widen the slopes, as this loose side-fill is not compacted and under the action of frost will nearly always slough away from the harder central portion.



To get the full benefit of the teaming in compacting the dirt, a deep fill should be started at a point nearest the cut from which the material is hauled and each load driven over the loose layer. In this way nearly every fill can be better compacted than by the use of a roller alone. For long fills where there is considerable teaming over each layer a roller is not usually needed.

Wet clay or heavy loam should never be placed in the bottom of a fill, as it dries slowly when not in contact with the air and keeps the fill "spongy." The writer has seen cases where fills not over 3 feet deep have remained soft for two months where wet material had been used and it was finally necessary to remove it.

Transferring Grade from Stakes. A handy level for transferring the grade from stakes to the center of the road is shown below. If well made it will transfer the grade elevation 50 feet with an error of less than 3 inches, which is close enough for this stage of the construction:

Ditches. The ditches *must always* be dug out enough to protect the center grading before the fine grading (stone trench) is completed, and it is usually cheaper for the contractor, as well as better for the road, to dig them out before the fine grading begins.

String Level.

FIG. 70

Regulation of Material in Fills. In fills, particularly shallow ones, the road can be greatly improved by a judicious selection of available materials. Material taken from two nearby cuts, or at different depths in the same cut, will often vary in character and the most experienced man on the job should indicate which materials to use in the center of the fill, under the metalling, and which on the sides. The soils in the order of value for fills are gravel, coarse sand, loam, and clay. For shallow fills on a good foundation clay should not be used under the stone, as mentioned on page 62, and a good material must be overhauled or borrowed. It is better to avoid overhaul if possible, as it is an item liable to be disputed as to the amount. Where it is neces-

sary, a good practical method of determining the amount of the small quantities of earth usually needed is to keep track of the number of wagon loads overhauled from station to station.

Sod may be used in the sides of the fill, but should be kept at least eleven feet off center. It should NEVER be used as a shoulder close to the stone or in the center of the fill under the metalling.

The author wishes to emphasize the importance of this regulation of material. At present the inspection of rough grading is often confined to keeping the sod from the center fill, and the center fill is made of the dirt just as it happens along. As a result, the subgrade will vary greatly in character and if a uniform depth of stone is used over this "spotty" fill the results are often not satisfactory, while if the depth of stone is varied to meet the subgrade conditions an unnecessary amount of stone is used. In cases where there is no choice of earth materials the stone depth must be made thick enough to meet the requirements of the grade.

FINE GRADING FOR STONE TRENCH

The fine grading includes the shaping and consolidation of the stone trench.

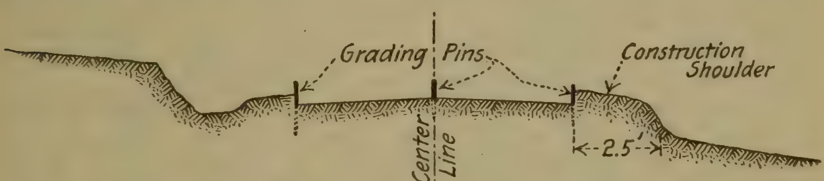


FIG. 71.—Showing 3 Lines of Grading Pins

The construction shoulder must be at least 2.5′ and well consolidated in order to hold the stone solidly during rolling. This must be watched continually by the inspector as it is a point often slighted.

Shaping the Grade. A simple guide for shaping the grade is shown in the accompanying sketch and consists of three strings (center and sides) stretched between pins driven at least every 50 feet and preferably every 25 feet. The pins should not be placed at intervals of more than 50 feet as this will cause objectionable sag in the lines and the grade will be undulating. The grade elevation is transferred and the lines carefully set at their proper elevation by means of a straight-edge, level and rod, or by stretching a line between grade stakes on opposite sides of the road as previously described. The string level recommended for rough grading cannot be used, as it is not sufficiently accurate.

The general level of the finished consolidated grade should be correct to within 1 inch. This leeway of 1 inch from the figured grade makes it possible to get satisfactory results without wast-

ing time on finical work and does not appreciably affect the total amount of excavation, as the errors tend to balance. There should, however, be no short, small irregularities of grade noticeable to the eye. Continuous inspection on shaping the grade is not necessary.

Consolidating the Grade. Most soils when slightly moist will consolidate readily if thoroughly rolled. Clay, heavy loams, or excessively fine sandy loams (quicksand) will not pack when wet. Continued rolling is injurious for these soils in this condition, as they will "work" under the roller. If they occur only in small pockets they can be removed and replaced with good material; if in stretches of any length the grade must dry out before placing the stone. Under drains are constructed at this time, where necessary, and the surface ditches are cleaned out and made effective. Where a hard shower has softened the surface only of a previously consolidated grade of this kind and the contractor wishes to lay stone, the surface can be hardened by spreading a thin layer of gravel or waste No. 2 stone and rolling it into the earth. This will help in preventing the stone teams from cutting up the grade.

Gravels and finely pulverized clay, or clay loams (deep dust), will not consolidate when dry; such material must be thoroughly sprinkled to get a compact grade. It is not, however, customary to sprinkle coarse gravels, even if slightly loose, as no objectionable results follows from placing stone on such a grade; deep clay or loam dust is objectionable and must be sprinkled.

Coarse sand makes an ideal foundation but is hard to keep in shape while placing the first layer of stone. In some cases sprinkling will harden it sufficiently; in others a layer of fine loam has been spread over the sand and flushed in with satisfactory results. Sometimes where loam is not available a cheap cheese-cloth has been spread over the top of shifting sand to prevent the stone from punching in too much under the roller. The author has never encountered any coarse sand that could not be successfully treated by sprinkling and covering with 1 inch or 2 inches of No. 2 stone; the blanket of No. 2 stone prevents the sand from squeezing up into the loose bottom stone and spreading the fragments.

While coarse sand makes a good foundation, a fine sand or sandy loam approaching quicksand is very treacherous; it is difficult to judge the degree of fineness at which a sand becomes treacherous, particularly when it is dry. A laboratory method is given on page 64, but a good practical method in the field is to saturate the material thoroughly with water; a satisfactory sand becomes more compact while an exceedingly fine sand gets "quaky."

DETERMINATION OF STONE DEPTHS AND CONSTRUCTION OF SUB-BASE

Practically the only engineering problem that the constructing engineer has to solve is that of foundations. It is recognized by most designers and estimators that it is impossible from even a careful preliminary examination of the soil to specify exactly the amounts and depths of foundation stone. To meet this an extra quantity of sub-base or bottom stone is allowed the constructor, to be used as he sees fit. During the progress of the rough and fine grading the exact limits of the different kinds of subgrade soil are determined and the stone depths varied according to his judgment. (See page 64.) Men that really understand this part of the work are hard to get, as it is only from extended experience and intelligent study of their own failures and successes that a sound judgment is developed. A good constructing engineer is much more difficult to find at present than a good technical designer.

Where sub-base is used the subgrade is dug out to the required extra depth and rolled if it is in such shape that it will not "work." Peat, muck, wet fine sand, or wet clay cannot be rolled until the sub-base is placed and filled. Where it is possible, such soils should be drained and allowed to dry before placing the base, but is often not feasible to dry them enough to allow rolling, even though underdrainage is put in, which partially hardens them and successfully protects the road after the stone has been placed. This is particularly true on flats where it is hard to get an outlet for a drain or in the fine sands on which an under drain has little effect on account of the capillary action of the material. Where a soft subgrade of this kind is encountered, a stony gravel makes the best sub-base, as it contains no voids between the larger fragments and when rolled the soft underlying material cannot squeeze up through the course. In case boulder or quarry stone base is used on a soft grade, it is necessary to lay them in close contact by hand and then fill the voids completely with gravel or No. 2 stone *before* rolling; otherwise the subgrade material would squeeze up between the stones, separating them and partially destroying the efficiency of the base.

In the Spring and Fall of the year it is common to find good material so saturated from long-continued rains that it acts badly under the roller and instead of waiting for the grade to dry out, when the normal thickness of stone would be sufficient, sub-base is often put in either to help the contractor so that he will not be delayed or because the engineer is misled as to the character of the material. This results in a waste of money. On the other hand, clay, when thoroughly dry, is hard and firm, which often influences a new man to omit sub-base where it will surely be needed.

The use of sub-base should not depend too much on the action of the grade under the roller unless the degree of saturation of

the material is considered, although it serves as a guide in locating doubtful spots. The final determination should depend on test pits, which develop the character of the underlying material.

The sub-base is constructed, as explained, in the chapter on Foundations, either of gravel, boulder or quarry stone. The depth is gauged by lines. The ratio of loose to rolled depth is given on page 272.

Continuous imspection is not needed on sub-base; the depth of grading is checked before the stone is placed and the width, depth, and workmanship can be readily determined after the base is completed, and by an occasional inspection during the progress of the work.

Bottom Stone. The earth subgrade must be firm and compact before the stone is spread. Bottom stone must NEVER be laid on a soft grade. One of the most common slips of inspection is to allow this to be done and the result is a "punky" bottom course that is never up to standard. The distributing power of this course depends largely on the stone fragments being firmly interlocked; if the stone is placed on a soft grade and rolled, the earth will squeeze up between the fragments and separate them.

The depth of the loose stone is gauged by the lines or cubical wooden blocks placed on the subgrade. Blocks are more convenient than lines except over sub-base of stone fills, where lines must be used to get a spread true to shape and grade. The ratio of loose to rolled depths is given on page 272.

The loose stone is rolled until the stones are solidly interlocked and there is no movement under the roller. A thin layer of satisfactory filler (see materials page 129.) is spread over the top, rolled and broomed in; the process is repeated until the stone is thoroughly filled. Continuous inspection on bottom course is not necessary. The widths and depths can be readily checked by occasional inspection. The two points to be carefully watched during construction are: 1. That the grade is firm; 2. that the loose fragments are thoroughly rolled *before* the filler is applied.

It is desirable to complete the bottom course well in advance of the top, in which case the contractor can work to advantage after rains, and the course will be better compacted by subjecting it to some traffic action.

Where local stone is crushed on the job and the stone used ranges in size from 1 in. to tailings, care must be used in spreading that the sizes are well mixed, as pockets of fine or coarse stone are objectionable. The simplest method of mixing is to run the No. 3 and No. 4 and tailings into one bin at the crusher; if they are separated they can be well mixed by loading one end of the wagons with the No. 3 and the other end with No. 4 and when dumped on the grade they will run together. When difficulty is experienced with these methods in obtaining a well-mixed stone spread the loose stone can be harrowed. Many specifications call for harrowing thoroughly where a large range

of crushed stone size are allowed in one course. If possible, tailings should be used as sub-base. When used in the bottom course having a rolled depth of 4 or 5 inches they should be placed in the lower part of the course, but for a 3-inch depth they should be placed on top and broken with a knapping hammer into fragments of less than $3\frac{1}{2}$ inches.

The filler should not be dumped directly on the stone unless absolutely necessary. Drawing the loads onto the unfilled stone loosens the course, and, also, at each pile of filler there is apt to be left an excess which is hard to clean off.

Table 52 gives the approximate amount of filler required per 100 feet, and the spacing of $1\frac{1}{2}$-yard loads. The amount varies for the different materials used.

Grading and foundations have been treated at some length, as they are the most difficult parts of the construction.

Table 52. Giving the Approximate Amount of Filler Pe-quired per 100 Feet of Road for Crushed Stone Macadam Bottom Courses of Different Widths and Depths, Using 0.35 Cubic Yards of Filler per Cubic Yard of Rolled Bottom

Width of M'cadam	Rolled Depth of Bottom Course			
	3″	4″	5″	6″
10′	3.2 cu. yds.	4.3 cu. yds.	5.4 cu. yds.	6.6 cu. yds.
12′	3.8 “ “	5.1 “ “	6.5 “ “	7.6 “ “
14′	4.5 “ “	6.0 “ “	7.5 “ “	9.0 “ “
15′	4.9 “ “	6.4 “ “	8.0 “ “	9.9 “ “
16′	5.2 “ “	6.9 “ “	8.6 “ “	10.4 “ “
18′	5.9 “ “	7.9 “ “	9.7 “ “	11.8 “ “
20′	6.4 “ “	8.6 “ “	10.8 “ “	12.8 “ “
22′	7.0 “ “	9.4 “ “	11.8 “ “	14.2 “ “

Table 52A. Giving the Approximate Spacing of 1.5 Cubic Yard Loads of Filler for the Widths and Depths shown in Table 52

Width of Macadam	Rolled Depth of Bottom Course			
	3″	4″	5″	6″
10′	46 feet	34 feet	27 feet	23 feet
12′	40 “	30 “	23 “	20 “
14′	33 “	25 “	20 “	17 “
15′	31 “	23 “	19 “	15 “
16′	29 “	22 “	17 “	13 “
18′	25 “	19 “	16 “	12 “
20′	23 “	18 “	13 “	11 “
22′	21 “	16 “	12 “	10 “

TOP COURSES

Waterbound Top. Waterbound top is constructed in the same way as the bottom course except that stone dust is used for a filler and the course is puddled as has been described.

If the stone used is a local stone crushed on the job the output of the crusher must be carefully controlled, especially where selected boulders are used, as it is very important that the size and quality of such stone shall be uniform.

Imported stone can be inspected on the cars. Aside from this, comparatively little inspection is required except at the stage when the loose stone has been rolled and before the binder is spread. At this time the inspector should examine the rolled course very carefully to see that it is true to shape and has no short depressions or humps. The smooth riding quality of the road depends on this inspection and too much care cannot be taken. This point is particularly emphasized, as many of the stone roads in New York State have been criticized as rough for automobile traffic. Any depressions are filled with stone of the same size as the body of the course and rolled, after which the course is again inspected and corrected until it is made true. The binder is then spread, broomed in dry, and puddled. In puddling use plenty of water and roll rapidly. If a pipe line and hose are used a pressure of 100 to 125 pounds at the pump should be maintained. The road can be conveniently puddled in stretches of 100 to 200 feet.

After the road has dried out and been opened to traffic, if raveling occurs it can usually be remedied by light sprinkling and rolling.

Where the top course is granite, gneiss, or trap, it is often necessary to use a certain percentage of limestone dust with the normal screenings. The limestone is more effective when spread last, filling the top voids of the course.

Bituminous Top. Penetration Method. The same procedure applies to the quality, size, and laying of the stone for a bituminous as for waterbound top, and does not require continuous inspection.

Just before pouring the bitumen the course should be carefully examined and any pockets of fine stone, dirt, dirty or dusty stone removed, as fine stone or dirt prevents the penetration of the binder and the bitumen will not adhere properly to the stone unless it is clean and dry. The course is not rolled as firmly at this stage as for waterbound tops because excessive rolling tightens the stone too much and prevents the penetration of the bitumen. There should, however, be no creep in front of the roller. The bitumen is poured into the voids of this *clean, dry, partially* compacted course, usually by means of hand-sprinkling pots or hods. Pots having vertical slots are preferable to the fan-spout pots, as they give better penetration.

Hods are to be preferred to pots. When hods are used, however, the bitumen should be poured across the road instead of in a

longitudinal direction as this prevents overlap and minimizes the difficulty of preventing humps or waves.

In placing the bitumen the following precautions must be observed: It must be hot enough to run freely; for each grade the temperature of applications is usually specified and it must *not* be overheated, for if charred it is useless. In applying, by whatever method, care must be taken not to overlap, as waves or humps will develop at these points. These defects do not appear for some time after the road is opened to travel, and an inexperienced inspector fails to realize the necessity of care in this particular. The stone must be clean and dry, and, in the writer's opinion, the air temperature should not be less than 50° F., as bitumen applied in cold weather is so chilled when it strikes the cold stone that an excessive amount is retained on the surface. As soon as the bitumen is applied a thin layer of No. 2 stone is spread over the surface and rolled lightly; continued rolling at this point is injurious, as freshly laid bituminous tops tend to shove under the roller and form waves. The road can be thoroughly rolled and shaped to advantage only after the bitumen has had some time to harden. Good results have been obtained by rolling thoroughly the succeeding day after the binder is applied, unless in the meantime rain has saturated the course, in which case it must be allowed to dry before rolling.

The amount of bitumen spread per square yard is usually controlled by spreading a given number of pots or hods in a given length of the road. These units of length can readily be marked off by the inspector with a stick or tape. This method will be satisfactory if checked up twice a day by the number of barrels used. When the binder is heated in small kettles it will sometimes catch fire, but this is usually due to scale which has collected in the tank and if cleaned out it generally remedies the trouble.

Where bituminous materials are heated by steam it is often convenient to know the temperature of steam at different pressures; the following table is inserted for this purpose:

TABLE 53

Pressure Gauge Lbs. per Sq. In.	Temperature of Steam °F	Pressure Lbs. per Sq. In.	Temperature °F of steam	Pressure Lbs. per Sq. In.	Temperature °F of steam
[1] 15	213	100	328	200	382
20	228	120	341	220	390
40	267	140	353	240	397
60	293	160	363	260	404
80	312	180	373	280	411
100	328	200	382	300	417

[1] Fifteen pounds normal air pressure; to get ordinary steam gauge reading subtract 15 lbs. from the values given in this table.

HASSAM CONCRETE PAVEMENT

By E. E. Kidder

The principal mechanical difficulty in laying a Hassam pavement is in getting a proper penetration of the grout.

This requires stone free from small particles and a grout of the proper consistency.

Stone. The stone should be sized $1\frac{1}{2}''$ to $3\frac{1}{2}''$ uniformly mixed. Any pockets of fine stone should be shoveled out or if they occur in small areas raked over till the fine goes to the bottom of the course.

The spreading is followed by rolling with a 10-ton road roller. Close attention should be given to obtaining as nearly a perfect surface as possible as it is practically impossible to add or deduct material once the stone is grouted.

Grout. The grout should penetrate to the bottom but should not be so thin that separation occurs. The size of sand is important. Coarse sand will not penetrate well. Sand passing a $10''$ mesh and containing much that is finer works well.

Manipulation. Each morning the end of the previous day's work should be cut down vertically and square across the road, shoveled out and replaced with new stone. This insures a vertical joint. *Continuous Inspection is Necessary on both Stone and Grout.* The grout will float a few of the top stone out of place but the 5-ton tandem roller will smooth them down. The final finish is obtained by hand tamping and brooming the surface. The tamping is absolutely necessary to get the best results and it will be neglected unless insisted upon.

Shoulders. It is desirable that the earth shoulders be left $1''$ higher than the finished pavement until the grouting is completed to prevent waste. During the rolling of the grout some water will flush to the surface and run to the edge; it should be let off by digging small trenches through the shoulder. The grading of the shoulders should be practically complete before laying stone in order that the Sand and Cement may be placed on one side of the road and the other shoulder may be used as a walk for the workmen and traffic. The gang organization is shown by a sketch (page 288 Cost Data).

FIRST CLASS CONCRETE PAVEMENTS

By F. W. Bristow

The sub-grade should be formed true to alignment, elevation and shape and consolidated well in advance of the mixing machine to permit the delivery of materials both on the sub-grade and shoulders.

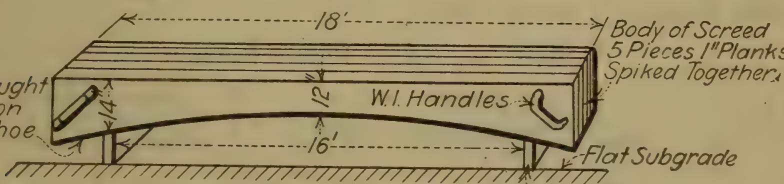
The materials, stone or screened gravel, sand and cement should be distributed uniformly in the proper quantities to construct the pavement as planned. (For quality of materials see specifications. For amounts required see Cost Data.) The cement should be delivered on the road only as required and covers provided for its protection in case of storm.

Inspection of Manipulation. A diagram showing a typical mixing gang organization is given in the chapter on Cost Data. Two inspectors are necessary to properly supervise the work. The inspection *must*

be continuous. The inspector ahead of the mixer sees that the sub-grade is correct; that the edging forms are properly set; that the fine and coarse aggregate conforms to the requirements, and that the proper amount of materials are placed in each batch of concrete.

He also should keep a daily record of the amount of cement used, the amount of concrete laid and should figure the amount of cement per cu. yd. of concrete as a check on his batch inspection. He should be careful to observe that no empty cement sacks from the previous days run are counted the second time.

The inspector back of the mixer first sees that the sub-grade is smoothed as the mixing machine moves ahead; that any muddy conditions is remedied by removal and that a dry dusty sub-grade is sprinkled to prevent rapid absorption of water from the concrete; that the concrete as delivered from the mixer has the proper consistency and is thoroughly mixed; that the transverse expansion joints are properly placed; that the striking of the concrete with the screed [1] or template is so done as to leave no projecting stone, or humps or hollows in the surface. Any surface irregularities must be immediately remedied and the mass restruck. The screeding is kept up closely to the mixer and is followed by the wood float finishers working from a bridge that spans the concrete.



Sketch of Screed
FIG. 71 A

In case surface brooming is required the inspector determines when it shall be done; the best time is just after the initial set starts. Long-handled steel brooms are used and the brooming is done lightly transversely to the road.

In hot weather the fresh concrete should be sprinkled to prevent sun checking. It is covered within 24 hours with a coat of earth 1″ to 2″ thick which is sprinkled and kept damp for 10 days when it is removed. Traffic must be barricaded from the road for this time.

Before turning traffic on to the completed concrete the earth shoulders should be finished along the edge to prevent spauling.

Sheet Asphalt, Topeka Mix, etc. The important points in any form of a mixed Bituminous surface are a proper grading of the aggregate and care not to char the binder in mixing.

Two inspectors are required; one at the plant and one where the asphalt is being laid. *Plant inspection should be continuous.* The plant inspector is responsible for the proper proportions of the different sizes of the aggregate and for the proper temperature of the mix. To insure the proper proportions he should test the measuring scales at short intervals and sift a sample of the dry mineral aggre-

[1] The screed should be two feet wider than the finished pavement as it progresses with a see saw movement rather than a direct full.

gate at least once a day. His most important duty is to prevent charring of the binder. It is not necessary to take the temperature of each batch as with a little experience any objectionable condition can be detected by the character of the smoke; a dense white smoke given off when mixing indicates a dangerously high temperature. When this is observed the batch should be tested with a thermometer and immediately rejected if over the specified temperature limit. (See specifications.) The temperature of the mineral aggregate will fluctuate very rapidly in the small plants generally used for road work and care should be observed in picking the plant inspector that he is a very conscientious man. He should also furnish the driver of each load of asphalt with a ticket giving the weight of the mix on that load.

The Inspector on the road records the temperature of the mix as received, the weight of each load and indicates to the spreaders the number of sq. yds it should cover.

(The surface mix weights approx. 100 lbs. per sq. yd. per inch of consolidated depth.)

He also should take a sample of the mix as delivered once a day and ship to the laboratory for check analysis.

The following sketches show a sample of a plant inspector's and road inspector's record book.

SEPT. 29, 1915. PLANT RECORD

Load Record				Bitumen Record	
Load	Time	Temperature of Mix.	Weight of Load	Time	Temperature
1	7.30	320° F.	50000 lbs.	7.00	310° F.
2	7.45	310	5000 "	8.00	345
3	7.55	300	6000 "	9.00	340
4	8.15	300	6000 "	10.00	310
5	8.25	290	5000 "	11.00	305
6 etc.	8.45	310	5000 "	12.00	320

TEST SAMPLE NO. 7. SEPT. 29, 1915. ROAD RECORD

Load No.	Time	Temperature of Mix.	Weight as per Ticket	No. Yds. Covered	Location on Road
1	8.00	310° F.	5000 lbs.	25	Sta. 10 + 30 to 10 + 42
2	8.20	300	5000 "	25	" 10 + 42 " 10 + 54
3	8.30	295	6000 "	30	" 10 + 54 " 10 + 69
4	8.45	295	6000 "	30	" 10 + 69 " 10 + 84
5 etc.	9.00	280	5000 "	25	" 10 + 84 " 10 + 96

Proportions of Mix. The proportions of mix should be determined by the engineer by screen analysis of the different materials that the contractor proposes to use.

As an example assume that a mixture of cement, fine sand, coarse sand and buckwheat stone is proposed and it is desired to determine the relative amounts of the different materials to use in order to get the correct proportion of sizes specified.

For all ordinary purposes a size analysis can be safely made using the following screens: #200, #80, #40, #10, $\frac{1}{4}''$ and $\frac{1}{2}''$.

The materials are thoroughly dried and the percentages expressed by weight.

Fine Sand (Feeder Pit)

Passing #200				5%
"	# 80 retained on #200			70%
"	# 40 "	" # 80		25%

GOOD QUALITY

Coarse Sand (Bauerman Pit)

Passing #200			1%
"	# 80 retained on #200		2%
"	# 40 "	" # 80	29%
"	# 10 "	" # 40	68%

Buckwheat Stone. (Commercial plant.)

Passing #200			1%
"	# 40 retained #200		2%
"	# 10 "	# 40	7%
"	$\frac{1}{4}''$ "	# 10	60%
"	$\frac{1}{2}''$ "	$\frac{1}{4}''$	30%

The proportions can now be varied to produce practically any required mix.

Tabulation Showing Method of Determining the Number of Pounds of Each Material to be Used in a 100 lb. Batch to Produce a Required Mix.

Material	No. lbs.	Bitumen	#200	#40	#10	$\frac{1}{4}$	$\frac{1}{2}$
Bitumen	10	10	—	—	—	—	—
Cement	7	—	7	—	—	—	—
Fine Sand	47	—	2.5	44.5	—	—	—
Coarse Sand	20	—	—	6.0	14.0	—	—
Buckwheat Stone	16	—	—	—	1.0	9.6	5.4
Totals	100	10	9.5	50.5	15.0	9.6	5.4

In this way the effect of varying any of the component parts of the mix can be readily seen and determined.

The total size of the batch is of course varied to suit the capacity of the plant.

The laboratory analysis of the daily sample taken on the road furnishes a check on the plant inspector.

Rollers. The best results can be obtained by the use of two tandem rollers; a light roller not over 5 tons for first compression to anneal the surface while hot and a heavier 8 to 10 ton roller for final compression and cross-rolling. This is more important where the asphalt is laid on a macadam base than when laid on concrete.

BRICK ROADS

To cover the points of construction of brick roads we cannot do better than to give "Instructions for Inspectors," by William C. Perkins, Resident Engineer, New York State Department of Highways. Mr. Perkins is well qualified to judge of this class of work.

Grading. "Read your specifications carefully and follow them in every particular.

"Do not let the contractor dig beyond the back slopes of your ditches. Your ditches should be straight, no sudden jogs; back slopes all true; no rubbish deposited back of the ditches, and be sure that your ditches drain.

"Follow your cross-sections as closely as possible. Try to aid the contractor to take care of his dirt so that when the road is cleaned up there will not be a great amount of material to be moved.

"Never make a shovel fill over 6 inches without rolling it.

"In making a heavy fill with dump wagons begin to dump at the end toward your dirt supply. Have each pile of dump dirt spread thin and draw the next load over this, which will help to pack it. All should then be thoroughly rolled.

"Examine your subgrade carefully, particularly when the roller is going over same, and if it waves or shakes under the roller, sub-base or drain should be put in, or the material dug out and the proper material put in. Do not make a fill with any old material found along the road. Use judgment in this particular.

"Clearing and grubbing does not mean the grubbing of sod. It means the cutting down of bushes, trees, etc. Remember that the life of your pavement is the condition of your subgrade. The same should be inspected by the engineer in charge before any stone or concrete is placed.

"Grade the full width of your macadam or concrete. Never deposit stone in the rut. Keep your sub-base free of ruts.

"If your roller is not working on other work roll your subgrade. You cannot roll it too much.

"Do not shift center line or grades until you have reported the necessity for it to headquarters, and if absolutely necessary give an estimate of the increase or decrease in quantities that such change would make.

"Shoulders should not contain sod within 18 inches of the macadam.

"Back slope all ditches 1 on $1\frac{1}{2}$. Be careful that your gutters are not too deep. Deep gutters where not necessary for drainage purposes make a road dangerous and must be avoided.

"In trimming shoulders and ditches a good inspector should be put on the work, and instructed to see that the contractor sets proper stakes. A stake should be set out from the edge of the macadam, and also one in the ditch, and should be set at least every 100 feet. The bottom of the ditch must be a true

grade, no depression, and the ditch alignment must be good. These stakes can be easily set with a 16-foot level board. When approaching a culvert it is not necessary to deepen the gutters until you reach within 50 feet of same, when a straight grade can then be run to the invert.

"In all cases be sure your ditches will carry water, and, I repeat, be sure they are not ragged and the back slopes are well graded. In trimming shoulders be sure there is no ridge next to the macadam.

"In setting your stakes for the shoulder work use the ordinates and distances shown on the standard section.

"**Subgrade**. Be sure that your subgrade has been properly graded so as to obtain 5 inches of concrete. If the contractor builds the curb first, a templet should be run over the curbing and test made to be sure that you have the correct depth.

"**Concrete Edging**. Stakes for concrete edging can be placed every 50 feet for line and grading, with the exception at change of grades and curves, where they should be placed every 25 feet.

"Be sure that your forms are properly set as to line and grade.

"With stakes 50 feet apart be careful that there is no sag in the line when the forms are set.

"If edging is set first it is better that the concrete be hand-mixed, as a machine turns out too large a quantity and cannot be placed in the proper time.

"See that your forms are wet before the concrete is placed, and if steel forms are used they should be oiled.

"Have a careful inspector on the mixing of the concrete for the edging and watch the mix.

"Keep track of the number of bags of cement used and see that the proper proportion of cement to the lineal foot of edging is obtained.

"Edging $6'' \times 10\frac{1}{2}''$ will use 1 bag in 12.95 feet
"Edging $8'' \times 10\frac{1}{2}''$ will use 1 bag in 9.73 feet
"Mixture, $1 - 2\frac{1}{2} - 5$.

"Make the mixture rather wet and spade the same thoroughly, using a hoe straightened and punched full of holes, or some similar instrument, so as to get a good face next to the forms.

"If you find you cannot get a good top surface keep the edging a couple of inches low, and about every third batch mix a batch of fine material and bring the edging up to the proper height, throughly working the same in.

"Do not get a plaster effect, but get a good top surface.

"Round both edges with a rounding tool, making the inner edge of a smaller radius than the outer edge.

"When the forms are taken down all spots which are honey-combed, or rough, should be floated at once with cement. A rough edging should not be left on any road.

"Have the contractor back up the edging as soon as possible.

"In warm weather the edging should be kept wet for, at least,

twenty-four hours. Have the contractor use care in delivering materials after the edging is built so that the edges of same are not broken by wagons, etc.

" A good edging is often ruined by carelessness on the part of the contractor.

" **Concrete Base.** Before laying base be sure that the foundation is in proper shape and of a proper depth.

" Lay the concrete rather wet and drag same with a heavy templet. Have men back of the templet with tamping irons or blocks, tamping the concrete. This is important if you wish to get a smooth surface, and you must insist that the concrete be well tamped.

" Be sure that you keep track of your bags, and, also, that the machine is working properly.

" For a 16-ft. road $11\frac{3}{4}$ bags will lay 10 ft. concrete base, mixture $1-2\frac{1}{2}-5$.

" After the day's run examine your base, and if there are any spots which are porous, grout same and check up your bags at the end of each day.

" If the weather is very hot the base should be kept wet for twenty-four hours.

" **Sand Cushion.** Sand for this cushion should be absolutely free of stones, and you must insist that the contractor screen same, if stones are in the sand delivered. No excuses will be taken for stones or pebbles in the cushion. Spread sand for a sufficient depth, then roll same with a small roller; then drag, roll again, and then drag with templet.

" This should be sufficient to give a firm cushion.

" The smoothness of the pavement depends on the proper form of the cushion.

" **Brick.** Great care must be used in obtaining proper brick surface.

" Be sure that your strips on the side expansion joints are in when the contractor starts to lay brick.

" Allow no pinning in at the ends under $2\frac{1}{2}$ inches.

" Be sure that the expansion joint is not ragged. It must be uniform in width, otherwise you will háve transverse cracks.

" All bricks should be laid with lugs in the same direction. This is a point that the bricklayers very often do not do. The bricks should be laid by experienced bricklayers, not by amateurs.

" After the brick are laid the contractor will start culling. Then you and your inspectors should carefully go over them, marking all soft[1] bricks to be taken out and rejected; all kiln-marked bricks to be turned over, and if not satisfactory to be taken out and used for pinning in; all overburned bricks,[2]

[1] Soft brick are found by sprinkling the pavement lightly; the soft or under-burned brick will absorb the moisture, rapidly becoming dull, while the good brick still glisten with the water.

[2] Over-burned brick are known by their color, which is much darker than the average.

which are burned to a cinder to be rejected. All underburned bricks, which, in your opinion, will not make a satisfactory pavement, to be rejected. All bronzed bricks (which have the appearance of overburned brick but this on one side only) to be turned over, and if satisfactory allowed to remain in the pavement.

" Be sure that you have culled all of the bricks before the pavement is rolled, for after the pavement is rolled if much culling is done you are liable to have a rough pavement. After the pavement is rolled go over same and mark all broken and spalled bricks, to be taken out or turned over.

" Be careful of all high and low bricks in the pavement, for same will wear badly when the road is finished.

" Be sure that your bricks are laid at right angles to the curb and are not wavy as to line.

" In no case allow any 'Dutchman'[1] in your pavement except on curves where absolutely necessary.

" **Grouting**. The grouting of the pavement is its life, and the greatest care must be used. Insist that all grout be placed on the pavement by the use of scoops from a box with unequal legs.

" The grout should be mixed in small quantities and of the exact proportions. The sand should be sharp, not too coarse nor too fine. Care should be taken in using lake sand, as same is probably not sharp and too heavy for the grout. As soon as the grout reaches the pavement it should, at once, be pushed into the joints by means of brooms or squeegees.

" It is best to use brooms on the first grouting and a squeegee on the second and third groutings.

" Be sure that the joints are well filled in the first grouting, and do not let the grout escape over the edging and be lost.

" Follow closely with the second grouting, otherwise the two groutings will not unite.

" Be careful that the second grouting does not overlap the first. After the second grouting examine the pavement carefully and, if necessary, put on a third grout to get flush joints.

" The pavement should be completely covered with grout and all joints should be well filled before you pass on same.

" Allow enough time for the grout to obtain initial set, and cover pavement with a layer of sand to protect same from the weather; and pavement should be kept wet for, at least, twenty-four hours.

" In no case permit traffic on the pavement under ten days; longer, if possible.

" **Expansion Joints**. Be careful in removing the expansion joint boards that you do not disturb the pinning-in bricks and break the bond. We found it advisable to use two wedge-shaped boards to make the expansion joints and loosen up the back one as soon as grouting was started.

[1] "Dutchman." Brick chipped to wedge shape to fill in between radial courses on curves.

"In pouring the asphalt filler be sure that the joints are absolutely clean the full depth. This is very important, or, otherwise, you will have cracks in the pavement. The joints are to be flushed with asphalt."

CULVERTS

Culverts are usually constructed before the road is graded. They should be completed well in advance of the macadam, because even though the back-fill is carefully tamped there is bound to be some additional settlement under traffic action, and if the macadam is laid over a fresh back-fill depressions are sure to develop which, if not repaired, make "thank-you-marms" in the road.

Cast-Iron Pipe. Trenches for pipe are dug the required depth, making the bottom wide enough to allow the joints to be properly calked. This requires a trench 18″ to 24″ wider than the pipe diameter, i.e., for a 12″ pipe the trench is 30″ to 36″. Bell holes are dug as shown in Fig. 72, so that the pipe will have a uniform bearing its entire length. At no point should it rest directly on boulders or ledge rocks. If the foundation is soft the pipe should be laid on a concrete base. For ordinary soils the only precaution the inspector need take is to prevent back-fill under the pipe.

FIG. 72

Unless the foreman is alert the trench is often excavated too much in some places, which are then back-filled. This is bad practice except where boulders are encountered which must be removed and the cavities back-filled with good material.

Pipe. The pipe is inspected for flaws; it is then placed in the trench with the bell end upstream. At each joint the spigot end is placed in the bell and forced against the shoulder, making a tight joint. The pipe is then lined correctly and a gasket of jute or oakum driven into the joint with an iron calking tool having a 2″ to 3″ offset, as shown in Fig. 73. The balance of the joint is then filled with a 1 to 1 cement mortar.

FIG. 73.—Steel Caulking Tool

The trench is then back-filled, care being taken not to throw the pipe out of line; the back-fill must be well tamped in layers not exceeding 6″, using heavy paver's rammers. A good working rule is to use two of the best men on the job tamping and the laziest man on the force throwing dirt to them.

Head-walls for Culverts. The face of the head-wall should extend beyond the end of the pipe, as it is difficult to get a good-looking connection if it is flush with the end.

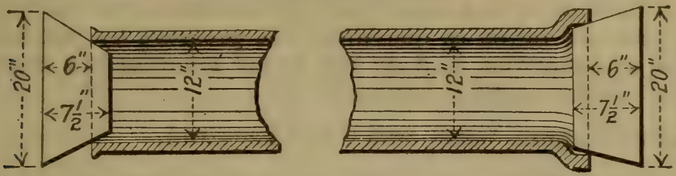


FIG. 74

Figure 74 shows a convenient plug form for this extension. This plug is set into the end of the pipe and can be readily removed; the resulting head-wall being pleasing in appearance. The head-wall form can, also, be readily skewed (set at an angle with the pipe) if required.

CONCRETE CULVERTS

Excavation. The trench is dug to the required depth; if the material will stand vertically no back forms are necessary, and the width of the trench is made the width of the out to out dimensions of the culverts. If back forms are needed the trench is usually made 2 feet wider. If running water is encountered which cannot be temporarily dammed, or diverted, the trench is made wide enough to flume the stream through on one side of the back forms for small culverts, or between the abutments for larger span structures.

Back-fill. The back-fill is made as for cast-iron pipe except that it should not be deposited on the fresh top of a culvert within twenty-four hours of laying the concrete.

Forms. Forms should be true to shape and constructed of planed tongue and groove lumber, for the exposed surfaces. They should be water-tight, as otherwise the fine material will run out of the face of the concrete and leave a rough " pop-corn " surface. They must be well braced to prevent bulging. Triangular or feather-edged grooved moldings are placed in the angles of the forms to shape them satisfactorily.

Removal of Forms. The length of time that the forms should remain in place is a matter of judgment; it depends upon the cement and weather conditions.

The author's practice is as follows:

Head-walls or parapet forms are removed within thirty-six hours in dry weather or within forty-eight hours in damp, cold weather, in order to rub down the surfaces.

Low side-wall forms for spans of 2′ to 3′, where the deck is constructed later, may be removed in 36 to 48 hours.

Trunk forms for small culverts 2′ to 3′ span may be removed in from 3 to 7 days.

Trunk forms for medium culverts up to 10′ span 7 to 14 days.

Deck forms for spans above 10′ may be removed in from 14 to 28 days.

Any unusual load, such as a roller, should not be allowed over a new culvert of even a small span in less than seven days, unless precautions are taken to distribute the pressure by planking the back-fill, or otherwise, and on the larger structures a time limit of three to four weeks is advisable.

Amount of Cement, Sand, and Stone required.

Table 49, page 304 gives these amounts for one yard of concrete.

The following table gives the amount of stone, sand, and cement required for culverts similar to Plate 6, assuming that no embedded boulders are used in the sides and bottom. If boulders are used see footnote, Table 49.

MIXING AND PLACING CONCRETE

The strength of the concrete depends largely upon the thoroughness of the mixing.

The author's practice has been as follows:

Hand-mixing. Cement and Sand.

3 turns dry....3d class concrete (foundations and side walls)
4 " " ....2d " " (decks and parapets)

Add water and mix mortar.

Drench stone and turn stone and mortar

3 times for 3d class concrete
4 " " 2d " "

Deposit in forms by dropping. Do not cast, as this separates the coarse and fine material. Use enough water to give a mixture that quakes like liver under the rammer.

Deposit in layers not over 6″ deep and ram each layer thoroughly; spade the concrete thoroughly, and work an excess of the fine stuff to the face of the forms by prying the larger fragments back from the form with a narrow spade or broad-tined fork.

Machine-mixing. Culverts generally contain such a small quantity of concrete that machine-mixing is rarely used. In case a batch-mixer is employed, the inspection is simplified to checking the quantities of cement, sand, and stone in each charge. If a continuous mixer is used it is well to keep watch of the cement hopper, as the cement is liable to run low, feeding only a portion of the worm, or a large lump of cement may ride on top of the worm and hinder the feed; or the worm may become coated with damp cement which reduces the capacity. If the inspector watches the cement hopper the contractor will tend to the sand and stone hoppers.

Finishing Concrete. If a smooth, marble-like surface is desired it can be obtained by rubbing down the surface before it has fully set with a cement sand brick moistened with water. If

Concrete Culverts

1.5′ high × 2.0′ wide							
Length Feet	Concrete Cubic Yards		Paving Square Yards	Ex. Met. Square Feet	Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.2	5.6	6.4	80	8.4	3.6	7.2
21	2.2	5.8	6.4	84	8.6	3.7	7.4
22	2.3	6.1	6.4	88	9.0	3.9	7.8
23	2.4	6.3	6.4	92	9.3	4.1	8.1
24	2.5	6.5	6.4	96	9.7	4.2	8.3
25	2.5	6.7	6.4	100	9.9	4.3	8.5
26	2.6	6.9	6.4	104	10.2	4.4	8.8
27	2.7	7.2	6.4	108	10.6	4.6	9.2
28	2.8	7.4	6.4	112	10.9	4.8	9.5
29	2.8	7.6	6.4	116	11.1	4.9	9.6
30	2.9	7.8	6.4	120	11.5	5.0	9.9
31	3.0	8.1	6.4	124	11.9	5.2	10.3
32	3.1	8.3	6.4	128	12.2	5.3	10.6
33	3.1	8.5	6.4	132	12.4	5.4	10.8
34	3.2	8.7	6.4	136	12.7	5.6	11.0
35	3.3	8.9	6.4	140	13.1	5.7	11.3
36	3.4	9.2	6.4	144	13.5	5.9	11.7
37	3.4	9.4	6.4	148	13.7	6.0	11.9
38	3.5	9.6	6.4	152	14.0	6.1	12.1
39	3.6	9.8	6.4	156	14.5	6.3	12.4
40	3.6	10.1	6.4	160	14.8	6.4	12.7
41	3.7	10.3	6.4	164	15.1	6.5	13.0
42	3.8	10.5	6.4	168	15.4	6.7	13.3
43	3.9	10.7	6.4	172	15.7	6.8	13.5
44	3.9	10.9	6.4	176	15.9	6.9	13.7
45	4.0	11.2	6.4	180	16.4	7.1	14.1
46	4.1	11.4	6.4	184	16.7	7.2	14.4
47	4.2	11.6	6.4	188	17.0	7.4	14.7
48	4.2	11.8	6.4	192	17.2	7.5	14.8
49	4.3	12.1	6.4	196	17.6	7.7	15.2
50	4.4	12.3	6.4	200	18.0	7.8	15.5

CONCRETE CULVERTS. — *Continued*

2′ high × 2′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Paving Square Yards	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.4	7.1	80	9.8	10.1	4.4	8.8
21	2.4	7.3	84	9.8	10.4	4.5	9.0
22	2.5	7.6	88	9.8	10.8	4.7	9.4
23	2.6	7.9	92	9.8	11.2	4.9	9.7
24	2.7	8.1	96	9.8	11.5	5.0	10.0
25	2.7	8.4	100	9.8	11.8	5.2	10.3
26	2.8	8.6	104	9.8	12.2	5.3	10.6
27	2.9	8.9	108	9.8	12.6	5.5	10.9
28	3.0	9.2	112	9.8	13.0	5.7	11.3
29	3.0	9.4	116	9.8	13.2	5.8	11.5
30	3.1	9.7	120	9.8	13.6	6.0	11.9
31	3.2	9.9	124	9.8	14.0	6.1	12.1
32	3.3	10.2	128	9.8	14.4	6.3	12.5
33	3.3	10.5	132	9.8	14.7	6.4	12.8
34	3.4	10.7	136	9.8	15.0	6.6	13.0
35	3.5	11.0	140	9.8	15.4	6.8	13.4
36	3.6	11.2	144	9.8	15.8	6.9	13.7
37	3.6	11.5	148	9.8	16.1	7.1	14.0
38	3.7	11.8	152	9.8	16.5	7.2	14.4
39	3.8	12.0	156	9.8	16.8	7.4	14.7
40	3.9	12.3	160	9.8	17.3	7.6	15.0
41	3.9	12.5	164	9.8	17.5	7.7	15.2
42	4.0	12.8	168	9.8	17.9	7.9	15.6
43	4.1	13.1	172	9.8	18.3	8.0	16.0
44	4.2	13.3	176	9.8	18.6	8.2	16.2
45	4.2	13.6	180	9.8	18.9	8.3	16.5
46	4.3	13.9	184	9.8	19.4	8.5	16.9
47	4.4	14.1	188	9.8	19.7	8.6	17.2
48	4.4	14.4	192	9.8	20.0	8.8	17.4
49	4.5	14.6	196	9.8	20.4	8.9	17.7
50	4.6	14.9	200	9.8	20.8	9.1	18.1

CONCRETE CULVERTS. — *Continued*

2′ high × 3′ wide

Length Feet	Concrete Cubic Yards		Expended Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.3	7.6	100	78	10.5	4.6	9.2
21	2.4	7.9	105	81	11.0	4.8	9.6
22	2.5	8.2	110	85	11.4	5.0	9.9
23	2.6	8.5	115	88	11.8	5.2	10.3
24	2.6	8.8	120	91	12.1	5.3	10.6
25	2.7	9.1	125	95	12.5	5.5	10.9
26	2.8	9.4	130	98	13.0	5.7	11.3
27	2.9	9.7	135	101	13.4	5.9	11.7
28	3.0	9.9	140	105	13.7	6.0	12.0
29	3.1	10.2	145	108	14.1	6.2	12.3
30	3.2	10.5	150	112	14.6	6.4	12.7
31	3.3	10.8	155	115	15.0	6.6	13.1
32	3.4	11.1	160	118	15.4	6.8	13.4
33	3.5	11.4	165	122	15.9	7.0	13.8
34	3.6	11.7	170	125	16.3	7.2	14.2
35	3.7	12.0	175	128	16.7	7.3	14.6
36	3.8	12.2	180	132	17.0	7.5	14.8
37	3.9	12.5	185	135	17.5	7.7	15.2
38	3.9	12.8	190	139	17.8	7.8	15.5
39	4.0	13.1	195	142	18.2	8.0	15.9
40	4.1	13.4	200	145	18.6	8.2	16.2
41	4.2	13.7	205	149	19.0	8.4	16.6
42	4.3	14.0	210	152	19.5	8.6	17.0
43	4.4	14.3	215	156	19.9	8.7	17.3
44	4.5	14.5	220	159	20.2	8.9	17.6
45	4.6	14.8	225	162	20.7	9.1	18.0
46	4.7	15.1	230	166	21.1	9.2	18.4
47	4.8	15.4	235	169	21.5	9.4	18.7
48	4.9	15.7	240	172	21.9	9.6	19.1
49	5.0	16.0	245	176	22.4	9.8	19.5
50	5.1	16.3	250	179	22.8	10.0	19.8

CONCRETE CULVERTS. — *Continued*

2′ high × 4′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.7	8.4	120	78	11.8	5.2	10.3
21	2.8	8.7	126	81	12.3	5.3	10.7
22	2.9	9.0	132	85	12.7	5.6	11.0
23	3.1	9.3	138	88	13.2	5.8	11.5
24	3.2	9.7	144	91	13.8	6.0	12.0
25	3.3	10.0	150	95	14.2	6.2	12.3
26	3.4	10.3	156	98	14.6	6.4	12.7
27	3.5	10.6	162	101	15.0	6.6	13.1
28	3.6	10.9	168	105	15.5	6.8	13.4
29	3.7	11.2	174	108	15.9	6.9	13.8
30	3.8	11.5	180	112	16.3	7.1	14.2
31	3.9	11.9	186	115	16.8	7.4	14.6
32	4.0	12.2	192	118	17.3	7.6	15.0
33	4.2	12.5	198	122	17.8	7.8	15.5
34	4.3	12.8	204	125	18.3	8.0	15.9
35	4.4	13.1	210	128	18.7	8.2	16.2
36	4.5	13.4	216	132	19.1	8.4	16.6
37	4.6	13.8	222	135	19.6	8.6	17.1
38	4.7	14.1	228	139	20.1	8.7	17.4
39	4.8	14.4	234	142	20.5	9.0	17.8
40	4.9	14.7	240	145	20.9	9.1	18.2
41	5.0	15.0	246	149	21.4	9.4	18.6
42	5.2	15.3	252	152	21.9	9.6	19.1
43	5.3	15.6	258	156	22.3	9.8	19.4
44	5.4	16.0	264	159	22.9	10.0	19.9
45	5.5	16.3	270	162	23.3	10.2	20.2
46	5.6	16.6	276	166	23.7	10.4	20.6
47	5.7	16.9	282	169	24.1	10.6	21.0
48	5.8	17.2	288	172	24.6	10.8	21.3
49	5.9	17.5	294	176	25.0	10.9	21.7
50	6.0	17.8	300	179	25.4	11.1	22.1

CONCRETE CULVERTS. — *Continued*

3′ high × 3′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.3	10.4	100	82	13.4	5.9	11.8
21	2.4	10.8	105	85	13.9	6.2	12.3
22	2.5	11.2	110	88	14.4	6.4	12.7
23	2.6	11.5	115	92	14.9	6.6	13.1
24	2.6	11.9	120	95	15.3	6.8	13.5
25	2.7	12.2	125	99	15.7	7.0	13.8
26	2.8	12.6	130	102	16.2	7.2	14.3
27	2.9	13.0	135	105	16.8	7.4	14.8
28	3.0	13.3	140	109	17.2	7.6	15.1
29	3.1	13.7	145	112	17.7	7.9	15.6
30	3.2	14.0	150	116	18.2	8.1	16.0
31	3.3	14.4	155	119	18.7	8.3	16.4
32	3.4	14.8	160	122	19.2	8.5	16.9
33	3.5	15.1	165	126	19.6	8.7	17.3
34	3.6	15.5	170	129	20.2	8.9	17.6
35	3.7	15.8	175	133	20.6	9.1	18.1
36	3.8	16.2	180	136	21.1	9.4	18.6
37	3.9	16.6	185	139	21.6	9.6	19.0
38	3.9	16.9	190	143	22.0	9.7	19.3
39	4.0	17.3	195	146	22.5	10.0	19.8
40	4.1	17.6	200	150	22.9	10.2	20.1
41	4.2	18.0	205	153	23.4	10.4	20.6
42	4.3	18.4	210	156	24.0	10.6	21.1
43	4.4	18.7	215	160	24.4	10.8	21.4
44	4.5	19.1	220	163	24.9	11.0	21.9
45	4.6	19.4	225	167	25.4	11.2	22.3
46	4.7	19.8	230	170	25.9	11.4	22.7
47	4.8	20.2	235	173	26.4	11.7	23.2
48	4.9	20.5	240	177	26.8	11.9	23.6
49	5.0	20.9	245	180	27.4	12.1	24.0
50	5.1	21.2	250	184	27.8	12.3	24.4

Concrete Culverts. — *Continued*

3′ high × 4′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.7	11.3	120	82	14.8	6.5	13.0
21	2.8	11.7	126	85	15.3	6.8	13.5
22	2.9	12.1	132	88	15.8	7.0	13.9
23	3.1	12.5	138	92	16.5	7.3	14.5
24	3.2	12.9	144	95	17.0	7.5	14.9
25	3.3	13.2	150	99	17.4	7.7	15.3
26	3.4	13.6	156	102	18.0	7.9	15.8
27	3.5	14.0	162	105	18.5	8.2	16.3
28	3.6	14.4	168	109	19.0	8.4	16.7
29	3.7	14.8	174	112	19.6	8.7	17.2
30	3.8	15.2	180	116	20.1	8.9	17.6
31	3.9	15.6	186	119	20.6	9.1	18.1
32	4.0	16.0	192	122	21.1	9.4	18.6
33	4.2	16.4	198	126	21.8	9.6	19.1
34	4.3	16.8	204	129	22.3	9.8	19.6
35	4.4	17.1	210	133	22.8	10.1	20.0
36	4.5	17.5	216	136	23.3	10.3	20.4
37	4.6	17.9	222	139	23.8	10.5	20.9
38	4.7	18.3	228	143	24.3	10.8	21.3
39	4.8	18.7	234	146	24.9	11.0	21.8
40	4.9	19.1	240	150	25.4	11.2	22.3
41	5.0	19.5	246	153	25.9	11.4	22.7
42	5.1	19.9	252	156	26.5	11.7	23.2
43	5.3	20.3	258	160	27.1	12.0	23.7
44	5.4	20.7	264	163	27.7	12.2	24.2
45	5.5	21.0	270	167	28.1	12.4	24.6
46	5.6	21.4	276	170	28.6	12.6	25.0
47	5.7	21.8	282	173	29.1	12.9	25.5
48	5.8	22.2	288	177	29.7	13.1	26.0
49	5.9	22.6	294	180	30.2	13.3	26.4
50	6.0	23.0	300	184	30.7	13.6	26.9

CONCRETE CULVERTS. — *Continued*

4′ high × 4′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.7	14.5	120	87	18.1	8.1	15.9
21	2.8	15.0	126	90	18.7	8.3	16.5
22	2.9	15.4	132	94	19.2	8.6	17.0
23	3.1	15.9	138	97	20.0	8.9	17.6
24	3.2	16.4	144	100	20.6	9.2	18.2
25	3.3	16.8	150	104	21.1	9.4	18.7
26	3.4	17.3	156	107	21.8	9.7	19.2
27	3.5	17.7	162	111	22.3	9.9	19.7
28	3.6	18.2	168	114	22.9	10.2	20.2
29	3.7	18.7	174	117	23.5	10.5	20.8
30	3.8	19.1	180	121	24.1	10.7	21.2
31	3.9	19.6	186	124	24.7	11.0	21.8
32	4.0	20.1	192	128	25.3	11.3	22.4
33	4.2	20.5	198	131	26.0	11.6	22.9
34	4.3	21.0	204	134	26.6	11.9	23.5
35	4.4	21.4	210	138	27.1	12.1	24.0
36	4.5	21.9	216	141	27.8	12.4	24.5
37	4.6	22.4	222	145	28.4	12.6	25.1
38	4.7	22.8	228	148	28.9	12.9	25.5
39	4.8	23.3	234	151	29.6	13.1	26.1
40	4.9	23.8	240	155	30.2	13.4	26.6
41	5.0	24.2	246	158	30.7	13.7	27.1
42	5.1	24.7	252	162	31.4	14.0	27.7
43	5.3	25.2	258	165	32.1	14.3	28.3
44	5.4	25.6	264	168	32.6	14.5	28.8
45	5.5	26.1	270	172	33.3	14.8	29.3
46	5.6	26.5	276	175	33.8	15.0	29.8
47	5.7	27.0	282	179	34.4	15.3	30.3
48	5.8	27.5	288	182	35.1	15.6	30.9
49	5.9	27.9	294	185	35.6	15.8	31.4
50	6.0	28.4	300	189	36.2	16.1	31.9

CONCRETE CULVERTS. — *Continued*

3′ high × 5′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	4.0	12.4	140	83	17.5	7.7	15.2
21	4.2	12.8	147	86	18.1	7.9	15.7
22	4.4	13.3	154	90	18.9	8.3	16.4
23	4.6	13.7	161	93	19.5	8.6	17.0
24	4.7	14.1	168	96	20.1	8.8	17.4
25	4.9	14.5	175	100	20.7	9.1	18.0
26	5.1	14.9	182	103	21.4	9.3	18.5
27	5.3	15.4	189	106	22.1	9.6	19.2
28	5.4	15.8	196	110	22.6	9.9	19.7
29	5.6	16.2	203	113	23.3	10.2	20.2
30	5.8	16.6	210	117	23.9	10.5	20.8
31	5.9	17.0	217	120	24.5	10.7	21.2
32	6.1	17.4	224	123	25.1	11.0	21.8
33	6.3	17.9	231	127	25.9	11.3	22.4
34	6.5	18.3	238	130	26.5	11.6	23.0
35	6.6	18.7	245	134	27.1	11.8	23.5
36	6.8	19.1	252	137	27.7	12.1	24.0
37	7.0	19.5	259	140	28.4	12.4	24.6
38	7.2	19.9	266	144	29.0	12.7	25.1
39	7.3	20.4	273	147	29.6	12.9	25.7
40	7.5	20.8	280	150	30.3	13.2	26.2
41	7.7	21.2	287	154	30.9	13.5	26.8
42	7.8	21.6	294	157	31.5	13.7	27.3
43	8.0	22.0	301	161	32.1	14.0	27.8
44	8.2	22.4	308	164	32.8	14.3	28.4
45	8.4	22.9	315	167	33.4	14.6	29.0
46	8.5	23.3	322	171	34.1	14.8	29.5
47	8.7	23.7	329	174	34.7	15.1	30.0
48	8.9	24.1	336	177	35.3	15.3	30.6
49	9.1	24.5	343	181	36.0	15.6	31.2
50	9.2	24.9	350	184	36.5	15.9	31.6

CONCRETE CULVERTS. — *Continued*

4′ high × 5′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	4.0	15.8	140	88	21.0	9.2	18.4
21	4.2	16.3	147	92	21.7	9.6	19.0
22	4.4	16.8	154	95	22.5	9.9	19.7
23	4.6	17.2	161	99	23.1	10.2	20.2
24	4.7	17.7	168	102	23.7	10.5	20.8
25	4.9	18.2	175	105	24.5	10.8	21.4
26	5.1	18.7	182	109	25.2	11.1	22.1
27	5.3	19.2	189	112	26.0	11.5	22.7
28	5.4	19.7	196	116	26.6	11.7	23.3
29	5.6	20.2	203	119	27.4	12.1	23.9
30	5.8	20.7	210	122	28.1	12.4	24.6
31	5.9	21.2	217	126	28.8	12.7	25.1
32	6.1	21.7	224	129	29.5	13.0	25.8
33	6.3	22.1	231	133	30.2	13.3	26.3
34	6.5	22.6	238	136	30.9	13.6	27.0
35	6.6	23.1	245	139	31.5	13.9	27.6
36	6.8	23.6	252	143	32.3	14.2	28.2
37	7.0	24.1	259	146	33.0	14.5	28.8
38	7.2	24.6	266	150	33.8	14.9	29.5
39	7.3	25.1	273	153	34.4	15.1	30.1
40	7.5	25.6	280	156	35.2	15.5	30.7
41	7.7	26.1	287	160	35.9	15.8	31.3
42	7.8	26.6	294	163	36.6	16.1	31.9
43	8.0	27.0	301	167	37.2	16.4	32.5
44	8.2	27.5	308	170	38.0	16.7	33.1
45	8.4	28.0	315	173	38.7	17.0	33.8
46	8.5	28.5	322	177	39.3	17.3	34.3
47	8.7	29.0	329	180	40.1	17.6	35.0
48	8.9	29.5	336	184	40.9	18.0	35.6
49	9.1	30.0	343	187	41.6	18.3	36.3
50	9.2	30.5	350	190	42.2	18.6	36.8

CONCRETE CULVERTS. — *Continued*

5′ high × 5′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	4.0	19.5	140	93	24.7	11.0	21.8
21	4.2	20.0	147	96	25.5	11.3	22.5
22	4.4	20.6	154	100	26.3	11.7	23.2
23	4.6	21.2	161	103	27.2	12.1	24.2
24	4.7	21.7	168	106	27.8	12.4	24.8
25	4.9	22.3	175	110	28.7	12.7	25.4
26	5.1	22.9	182	113	29.5	13.1	26.2
27	5.3	23.4	189	117	30.3	13.4	26.8
28	5.4	24.0	196	120	31.0	13.8	27.6
29	5.6	24.6	203	123	31.9	14.1	28.2
30	5.8	25.1	210	127	32.6	14.5	29.0
31	5.9	25.7	217	130	33.4	14.8	29.6
32	6.1	26.2	224	134	34.1	15.1	30.2
33	6.3	26.8	231	137	35.0	15.5	31.0
34	6.5	27.4	238	140	35.8	15.9	31.8
35	6.6	27.9	245	144	36.4	16.2	32.4
36	6.8	28.5	252	147	37.3	16.5	33.0
37	7.0	29.1	259	150	38.2	16.9	33.8
38	7.2	29.6	266	154	38.9	17.2	34.4
39	7.3	30.2	273	157	39.6	17.6	35.1
40	7.5	30.8	280	161	40.5	17.9	35.8
41	7.7	31.3	287	164	41.2	18.3	36.5
42	7.8	31.9	294	167	42.0	18.6	37.2
43	8.0	32.5	301	171	42.8	19.0	37.9
44	8.2	33.0	308	174	43.6	19.3	38.6
45	8.4	33.6	315	178	44.4	19.7	39.3
46	8.5	34.2	322	181	45.2	20.0	40.0
47	8.7	34.7	329	184	45.9	20.3	40.6
48	8.9	35.2	336	188	46.7	20.6	41.2
49	9.1	35.9	343	191	47.6	21.0	42.0
50	9.2	36.4	350	195	48.3	21.4	42.8

a rough sandpaper-like finish is wanted it can be secured by rubbing with a wooden float moistened with water. This finish is not as apt to hair-check as the smooth finish.

Freshly laid concrete should be protected from a hot sun by covering it with canvas, or blankets, and wetting it down frequently for four or five days. No plastering of surfaces should be allowed after the cement has set. If, however, it has been badly hair-checked from heat the defect can usually be remedied by rubbing with a carborundum brick. Freshly laid concrete must be protected from frost. A satisfactory method is to cover with canvas and a thick layer of manure or straw. If the concrete has been frost-pitted, on the surface only, bush hammering will give a rough stone finish, pleasing in appearance. No culvert work should be allowed in continued cold weather, as it is difficult to get a good finish and in roadwork there is no necessity of doing this work in the winter. Concrete inspection must be *continuous*.

CONCLUSION

For obvious reasons the inspection of construction is generally the weak point in Municipal and State Engineering undertakings. It is often due to the employment of inferior inspectors, and frequently to the impossibility of even good inspectors controlling certain contractors. The work is rarely bad, but it will not be as strong nor as lasting as a first-class job, and if such conditions are foreseen, and cannot be avoided, it is, perhaps, best to design the work stronger than would otherwise be required, as this seems to be the only practical method of meeting a recognized evil.

CHAPTER XII

SPECIFICATIONS

Under this heading are included extracts from the State specifications of New York and Washington covering "Materials" and the more common construction methods. It is difficult to write a specification that is definite and fair, and it is impossible to avoid criticism. The following clauses are examples of current practice. They are not ideal, but show the points to be considered. No attempt is made in this book to discuss methods of bidding or of forms of proposals.

MATERIALS

(New York State Specifications, 1914)

Materials of Construction

All materials proposed to be used in construction shall have due examination and pass all required tests before acceptance. Those which are to be tested by the Bureau of Tests at Albany shall have samples taken and submitted in accordance with the commission's instructions to its employees. Samples are to be taken of all sand, gravel, cement, concrete, bituminous material, stone, and all other pavement ingredients, of which the engineer in charge has not been notified that satisfactory samples have already been taken. None of this material is to be used until the written notification of acceptance is received by the engineer in charge of the contract, and then only so long as its quality remains equal to that of the accepted sample.

Portland Cement

0.1. All the cement used in the work shall be true Portland cement of well-known brands which have been in successful use on large engineering works in America for not less than two years and which are manufactured at works which have been in successful operation for at least one year.

0.2. Tests will be made as follows: — first, for fineness; second, for constancy of volume; third, for time of setting; fourth, for tensile strength; fifth, for composition by chemical tests; sixth, for specific gravity.

The average result of the separate samples shall be the test for tensile strength of any lot. The samples of each lot shall be required to show uniform results in tests. Marked deviations from such results may be considered cause for rejection, even though test requirements may be otherwise fulfilled.

The results of the tests may be expected in 12 days after shipment of samples.

Cement not satisfactory in the 7-day tests will be held awaiting the result of the 28-day tests before acceptance or rejection.

0.3. The cement shall meet the following requirements:

It shall be ground to such fineness that not less than 92 per cent by weight shall pass through a No. 100 standard sieve of 10,000 meshes per square inch, and not less than 75 per cent by weight shall pass through a No. 200 standard sieve of 40,000 meshes per square inch.

0.4. Pats of neat cement about 3 inches by 4 inches in size, ½ inch thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

Normal Tests

Air Test. One of these pats is then kept in air at normal temperature for 28 days.

Water Test: Another pat is kept in water maintained as near 70 degrees Fahrenheit as practical for 28 days.

Accelerated Test: A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for 5 hours.

These pats are observed at intervals and, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegration.

0.5. Cement shall not develop its initial set in less than 30 minutes, and shall develop a hard set in not less than 60 minutes nor more than 600 minutes, the determination being made with the Vicat needle apparatus from pastes of normal consistency, as follows:

The paste is molded upon a glass in a conical hard rubber mold 4 centimeters high; this cake is to set in moist air and a Vicat needle with a wire 1 millimeter in diameter and loaded to 300 grammes shall be placed upon it. When the needle ceases to pass a point 5 millimeters above the upper surface of the glass plate the initial set has taken place.

0.6. Briquettes of neat cement mixed 1 minute, in an air temperature between 65 and 70 degrees Fahrenheit and using water of about the same temperature, and put into the molds with fingers and trowel and kept in moist air at this temperature for 1 day of 24 hours, shall show an average tensile strength of one hundred and seventy-five (175) pounds per square inch.

Briquettes of neat cement mixed and molded as above and kept under above temperature for 1 day in moist air and 6 days in water shall show an average tensile strength of at least five hundred (500) pounds per square inch.

Briquettes of neat cement mixed and molded as above and kept under above temperature for 1 day in moist air and 27 days in water shall show an average tensile strength of six hundred (600) pounds per square inch.

Briquettes of 3 parts by weight of standard Ottawa sand and 1 part by weight of cement, mixed in the same manner as above and kept 7 days under the same conditions, shall show

an average tensile strength of at least two hundred pounds (200) per square inch.

Briquettes of sand and cement mixed and molded as above and kept under above conditions for 28 days shall show an average tensile strength of at least two hundred and seventy-five (275) pounds per square inch.

In the above tests for tensile strength the briquettes must not show any retrogression in strength within the periods specified.

0.7. The Commission of Highways may cause chemical tests, or analyses, of cement to be made, and may reject any cement which shows any adulteration, or excess of ingredients, which in its judgment would be detrimental to the work.

The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3) nor more than 4 per cent of magnesia (MgO).

0.8. The specific gravity of the cement after ignition to a low red heat shall not be less than 3.10; and the cement shall not show a loss in weight on ignition of more than 4 per cent.

0.9. The standard sand used in the tests shall be natural sand from Ottawa, Ill., screened to pass a No. 20 standard sieve of 400 meshes per square inch and be retained on a No. 30 standard sieve of 900 meshes per square inch.

Fine Aggregate for Concrete

0.10. Fine aggregate shall consist of sand free from organic matter; that which shows a coating on the grains shall not be used until satisfactorily washed. Sand shall be classified as No. 1, No. 2 and No. 3, and Grout Sand.

No. 1 Sand

0.11. No. 1 sand shall be of the following gradation: 100 per cent shall pass a $\frac{1}{4}$-inch screen; not more than 20 per cent shall pass a No. 50 sieve; and not more than 6 per cent shall pass a No. 100 sieve. In special cases where more than 20 per cent of a sand passes a No. 50 sieve and the sand is well graded to give a low percentage of voids, written permission for use of the sand may be given by the first deputy commissioner. Sand may be rejected for this class if it contains more than 5 per cent of loam and silt.

0.12. Mortar in the proportion of 1 part of cement to 3 parts of the sand to be tested shall develop a compressive strength at least equal to the strength of a similar mortar of the same age composed of the same cement and standard Ottawa sand.

No. 2 Sand

0.13. No. 2 sand shall fulfill all of the requirements for No. 1 sand except that restrictions on the percentage that will pass a No. 50 and No. 100 sieve shall be governed by the compressive strength of the mortar. The compressive strength of the mortar shall be at least equal to that obtained with the standard Ottawa sand.

No. 3 Sand

0.14. Sand may be rejected for this class if it contains more than 8 per cent of loam and silt. Mortar in the proportion of 1 part of cement to 3 parts of the sand when tested shall develop a compressive strength of at least 80 per cent of the strength of a similar mortar of the same age composed of the same cement and standard Ottawa sand.

Screenings

0.15. Screenings shall not be used as fine aggregate except to the extent and under the restrictions given below. The division engineer shall submit samples to the Bureau of Tests; they must pass the required tests; their use must be approved in writing by the First Deputy Commissioner.

0.16. Screenings may be substituted for a portion of the No. 1, 2 and 3 sand under the following conditions:

The screenings shall be free from dust coating and other dirt. 100 per cent shall pass a $\frac{1}{4}$ inch screen and not more than 6 per cent shall pass a No. 100 sieve. The compressive strength of a mortar in which the screenings and sand are in the proportions intended for use, shall be at least equal to the standard strength obtained with sand of the given class.

Grout Sand

0.17. Grout sand shall be a sand of which 100 per cent passes a No. 20 sieve, and not over 30 per cent a No. 100 sieve. Sand may be rejected for this class if it contains more than 5 per cent of loam and silt. The grains shall be free from coating.

Mortar in the proportion of 1 part of cement to 3 parts of the sand shall develop a compressive strength of at least 40 per cent of the strength of a similar mortar of the same age composed of the same cement and standard Ottawa sand.

Cushion Sand

0.18. Cushion sand shall be a sand of which 100% passes a No. 6 sieve and 90% passes a No. 20 sieve; an excessively fine sand will not be accepted in this class. Sand may be rejected for this class if it contains more than 10% of loam and silt.

Coarse Aggregate for Concrete

Stone

0.19. Crushed stone for concrete shall be of hard, durable stone, tested by the Bureau of Tests and satisfactory to the engineer. Stone for concrete shall be of an approved kind and quality of rock and shall be free, before being crushed, from soil, mud and dust. Crushed stone for first-class concrete shall be in fragments that will pass through a $1\frac{1}{4}$-inch circular hole and that will not pass through a $\frac{1}{4}$-inch square hole. Crushed stone for second-class or third-class concrete shall be in fragments that will pass through a $2\frac{1}{4}$-inch circular hole and that will not pass through a $\frac{1}{4}$-inch square hole.

Gravel

0.20. Gravel shall not be used in concrete except when it has been submitted by the Division Engineer to the Bureau of Tests, has been approved by the Bureau of Tests, and its use has been approved by the First Deputy Commissioner in writing, — and then only under the restrictions given below.

0.21. Gravel for use in concrete pavement and first-class concrete shall be composed of hard, durable stone absolutely clean and free from coating. No gravel will be accepted that contains any disintegrated or soft stone or shale. Gravel containing any flat stone shall not be permitted. Gravel for use in second and third class concrete shall be composed of a sound, durable stone. It shall be clean and free from coating. It shall not contain more than 10 per cent of soft stone or shale. Gravel containing a larger percentage of flat stone shall not be permitted.

0.22. Gravel for first-class concrete shall be in particles that will pass through a 1¼-inch circular hole and that will not pass through a ¼ inch square hole. Gravel for second and third-class concrete shall be in particles that will pass through a 2¼-inch circular hole and that will not pass through a ¼-inch square hole.

0.23. Gravel mixed with mud, clay, dirt or quicksand shall be washed to the satisfaction of the engineer. Run of bank gravel shall not be permitted. All gravel shall be properly screened and the coarse and fine aggregate regularly proportioned thereafter.

0.24. All coarse aggregate used for concrete shall be uniformly graded from the minimum to the maximum sizes of stone or gravel specified above for the several types of concrete, thus producing an aggregate in which the voids will be a minimum.

Stone, Gravel, etc., for Pavements

0.25. The sizes of all stone, gravel, etc., used under these specifications shall be determined by the size of screen aperture through which the stone will pass when revolved in a rotary screen. They shall be designated as follows:

Diameter of Aperture Min.	Max.	
	¼-inch square	Screenings
¼-inch square	⅝-inch circular	No. 1
⅝-inch circular	1¼-inch circular	No. 2
1¼-inch circular	2¾-inch circular	No. 3
2¾-inch circular	3¾-inch circular	No. 4

0.26. Gravel shall consist of clean, sound, tough hard stone. Gravel shall be separated into five grades or sizes by means of a rotary screen having openings as specified above for broken stone. All the general specifications given below relating to broken stone shall apply to gravel, excepting that gravel may contain not more than 5 per cent. of loam, but must otherwise be free from

dirt or foreign matter and shall be washed if so directed by the engineer.

0.27. Broken slag shall be approved acid slag, clean, sound, tough, hard, sharp-angled and weigh not less than 1,800 pounds per cubic yard. If specified for use, it shall conform to all the general requirements for broken stone as specified below.

0.28. Broken stone shall be clean and sharp angled, shall pass the standard tests for abrasion and toughness as adopted by the American Society for Testing Materials, and shall be approved by the Bureau of Tests and acceptable to the engineer before being used.

0.29. Field stones, boulders, or fence stones which are crushed for macadam purposes shall be 6 or more inches in diameter, if consisting of rounded cobbles. If of the flat variety, the minimum thickness shall be 2 inches, which latter requirement will also apply to laminated quarry stone.

0.30. If after trial it is found that partially developed quarries, ledges or other sources of supply do not furnish a uniform product, or if, for any reason, the product from any source, at any time, proves to be unsatisfactory to the engineer, said engineer may require the contractor to furnish stone from other sources of supply, and the contractor shall have no claim for increased payment on account of such requirement.

0.31. The contractor shall furnish one or more stone crushing plants of type, composition, and capacity satisfactory to the engineer. The rotary screens shall be provided with openings of size and shape given under "Stone Sizes," unless otherwise ordered by the engineer.

All crushing plants installed on the work shall be fitted up with a tailing chute so that no stone will reach the bins other than that which passes through the proper screen.

0.32. All stone must be of the required size when placed in the roadway, and no breaking up of stone by hammers or otherwise will be permitted after the stone has been placed in the work.

0.33. In no case shall any constituent of macadam pavement be dumped into place in mass; the final placing shall be by shovel or by thin spreading such that no appreciable fall occurs.

Filler or Binder. The filler for the bottom course shall be clean, coarse sand or stone screenings supplemented by product of the crusher not otherwise used in top or bottom courses. The filler and wearing surface for the top course shall be of top course stone screenings and when bituminous binder is used screenings must be dry, free from dust, and not larger than will pass a $\frac{5}{8}$-inch screen.

BITUMINOUS MATERIALS

Methods of Testing Bituminous Materials in the Laboratory of the Commission

Preparing Laboratory Samples. Each laboratory sample is usually composed of several samples that have been taken to represent one lot of material. The material in the separate samples is examined, and, if uniform in appearance, equal amounts are taken

from each and thoroughly blended to form a sample of about one-half pint on which the complete analysis is run.

In case of mineral bitumen, the sample received is thrown on a large piece of paper, pieces which are evidently foreign to the material are rejected, and the whole "quartered down" to a sample of about 300 grams. This is ground in a mortar and the analysis run on this part of the original sample.

Water Present. The presence of water in an oil, asphalt, or tar is determined by putting about 40 grams of the material into a deep, seamless 3-ounce tin box, a thermometer being suspended in the material. This is then heated to about 230° F. without stiring. If water is present, even in very small quantities, the material will froth when heated to about 212° F. The per cent of water present is determined by heating 20 grams of the material in a 2-ounce seamless tin box in an oven maintained at a temperature of 212° F. for an hour. The per cent of water in mineral bitumen is determined in a similar manner. The loss in weight, while not absolutely correct, is considered as moisture.

Homogeneity. The homogeneity of the mixture is shown by its general appearance at a temperature of 77° F. when in a melted condition and when examined under the microscope.

Gravity. The gravity is determined by taking a small test tube about $\frac{3}{8}$ of an inch by $3\frac{1}{4}$ inches, which is accurately weighed (weight A). The tube is then filled with distilled water at 77° F. and weighed (weight B). To get the gravity of the oil, asphalt, or tar the tube is filled with the material, cooled to a temperature of 77° F., cut off level with the top, and weighed (weight C). The gravity is determined as follows: $\frac{C - A}{B - A}$ = gravity.

Penetration. The penetration test is made by putting the material to be tested in a 3-ounce deep, seamless tin box. Melting the material at the lowest possible temperature, cooling in air and then placing the material in a bath, for one hour, maintained at the temperature at which the test is to be made. The penetration is the distance expressed in hundredths of a centimeter which a standard needle under a stated load, and at a stated temperature, will penetrate into the material. The factors usually employed are a No. 2 sewing needle, loaded with 100 grams, applied for five seconds at a temperature of 77° Fahrenheit.

Residue having a Penetration of 10 Millimeters. This test is made as follows: 50 grams of the oil are placed in a 3-ounce deep, seamless tin box, the box placed in a sand bath and heated over a Bunsen Burner. A thermometer is suspended in the oil, the bulb not touching the bottom of the box. The temperature of the oil is kept at from 480° F. to 500° F. and the oil is stirred from time to time with the thermometer to prevent overheating in any part. Depending upon the nature of the oil, as usually indicated by its flash, consistency at 77° F. and gravity, the operator can tell about what per cent it will be necessary to evaporate before cooling and taking a penetration as described under the test for penetration. It is sometimes necessary to make several trials before the desired

result is obtained. When the required penetration is reached, the residue left from evaporation is weighed and its per cent of the original sample taken is computed.

Ductility. The ductility of an asphalt cement or bitumen is determined by the distance in centimeters that a briquette of the material will draw out before breaking. The briquette of the asphalt cement is molded in a Dow briquette mold having a central cross-section 1 centimeter square, a 2-square centimeter cross-section at mouth of clips, and a distance of 3 centimeters between clips. The molding of the briquette is done as follows: The mold is placed on a brass plate. To prevent the asphalt cement from adhering to this plate and the inner sides of the two pieces of the mold, they shall be well amalgamated. The asphalt cement to be tested is poured into the mold while in a molten state, a slight excess being added to allow for shrinkage on cooling. After the asphalt cement is nearly cooled, the briquette is smoothed off level by means of a hot spatula. When it is thoroughly cooled to the temperature at which it is desired to make the test, the clamp and the two side-pieces are removed, leaving the briquette of asphalt cement held at each end by the ends of the mold which serve as clips. The test is made by pulling the two clips apart at a uniform rate of 5 centimeters per minute by means of hooks inserted in the eyes, until rupture occurs. The briquette is kept in water at 77° F. for at least 30 minutes before testing, and the test is performed while the briquette is so immersed in the water at the above temperature, and at no time is the temperature of the water allowed to vary more than half a degree from the standard temperature.

Toughness. The bitumen is heated until liquid; it is then poured into an amalgamated brass mold of such shape as to give a cylinder of the bitumen $1\frac{3}{4}$ inches in height by $1\frac{3}{4}$ inches in diameter. After cooling, the mold is removed and the cylinder of bitumen is placed in a mixture of finely crushed ice and water, giving a temperature of zero degrees centigrade. After remaining in the freezing mixture for about three hours the cylinders are broken in a Page impact machine (the standard machine of the American Society for Testing Materials for determining the toughness of macadam stone). When the cylinder to be broken is placed in the impact machine a piece of linen cloth about one inch square is placed on the end on which the plunger rests. This prevents the plunger from sticking to the bitumen and makes it easier to clean the machine. In making the test, the first drop of the hammer is from a height of five centimeters, and for each succeeding blow the height of the drop is increased five centimeters. The height from which the hammer falls when rupture occurs is given as the toughness of the material.

Melting Point of Bitumen. The melting or softening point of bitumen is determined by filling a ring $\frac{5}{8}$ inch in diameter by $\frac{1}{4}$ inch in depth, with the bitumen to be tested. After cooling, the bitumen is cut off level with the top of the ring. The ring containing the bitumen is placed in water at 41° F. for 20 minutes before making the test. In performing the test the ring is put in a support so placed that the bottom of the ring is 1 inch above the bottom of an 800 cc.

beaker. On the center of the bitumen in the ring, is placed a $\frac{3}{8}$-inch steel ball, a thermometer being placed with its bulb on a level with the ring containing the bitumen. The beaker is nearly filled with water at a temperature of 41° F. and the temperature raised at the rate of 8° F. to 10° F. per minute. The temperature recorded by the thermometer at the time the ball touches the bottom of the beaker is taken as the melting point of the bitumen.

Evaporation. Fifty grams of the material are weighed into a flat-bottomed dish $2\frac{3}{16}$ in. in diameter by $1\frac{3}{8}$ in. in depth. This is placed in an oven maintained at a uniform temperature of 325° Fahrenheit for a period of five hours. At the end of this period the loss in weight or per cent of loss is found by reweighing.

Flash. About 40 grams of the material to be tested are placed in a 3-ounce deep, seamless tin box. The box containing the material is placed on a sand bath over a Bunsen Burner, the bulb of a thermometer being placed in the material, but so adjusted as not to touch the bottom of the box. The flame of the Bunsen Burner is so adjusted that the temperature of the material being tested is raised at the rate of 10° F. to 15° F. per minute. As soon as vapors are seen coming off, the small flame from a capillary tube is passed over the center of the liquid and about $\frac{1}{4}$ inch above it, and repeated for about every 5° F. rise in temperature until the slight explosion indicates the flash-point is reached. The temperature at this point is recorded as the open flash-point of the material being tested.

Total Bitumen. The solubility in $C\ S_2$ is found by weighing approximately 1 gram of the material into an Erlenmeyer flask, adding 50 cc. of $C\ S_2$ and allowing the solvent to act 12 hours at laboratory temperature, care being taken to break up all lumps before filtering. The filtration is made through a C. S. & S. 9-centimeter filter paper No. 589. The papers are first dried, and weighed immediately before using. The filtration is made in a valve funnel, a watch glass beieg placed on the funnel to prevent evaporation of the solvent. After washing until washings come clean, the filter and residue are placed in an oven at 212° F. for 30 minutes, cooled in a desiccator and weighed. The difference in weight gives the amount of material insoluble in $C\ S_2$ from which the per cent of soluble bitumen is computed.

The total bitumen in mineral bitumen is determined by weighing about 25 grams of the dried material into a dried and weighed C. S. & S. extraction cartridge and extracting in a continuous extraction apparatus, using $C\ S_2$ for a solvent; drying and weighing after extraction is completed. The loss gives the amount of bitumen soluble in $C\ S_2$.

Carbon Tetrachloride Solubility. This test is made in the same manner as determining the bitumen soluble $C\ S_2$, except that $C\ C\ l_4$ is used as solvent.

Naphtha Solubility. The amount of material soluble in 76° naphtha (boiling point 140° F. to 190° F.) is found by the same method that is used in getting the amount soluble in $C\ S_2$, except that naphtha is used for a solvent in place of $C\ S_2$. The character of the filtrate is determined by placing about 10 cc. of the filtrate in the

tin covers of the 2-ounce boxes used in making the heating tests and allowing the filtrate to evaporate. The residue is noted to be sticky or oily by rubbing between the fingers.

Water Soluble Materials. Water soluble materials in tar are determined by weighing about 2 grams into a casserole, adding 50 cc. of distilled water, and boiling for 1 hour. The solution is then filtered into a weighted porcelain evaporating dish, using hot distilled water for a wash and evaporated to dryness on a steam bath. The weight at the evaporating dish and contents after drying to a constant weight at 212° F., less the weight of the dish itself, gives the amount of water soluble materials in the tar, from which the per cent may be calculated.

Free Carbon. The free carbon in tar is determined by extraction at room temperature with $C\ S_2$. In extraction $C\ S_2$ is used in the same manner as making the determination for the amount of bitumen soluble in $C\ S_2$ in asphalts. Determination as to whether extraction is complete is made by placing some of the carbon on white porcelain, moistening it with $C\ S_2$, and if the porcelain is stained the extraction is not complete, and the carbon requires more washing.

Paraffine. Fifty grams of the material are placed in a half-pint retort, E. & A. No. 4521, fitted with a tee condenser. To the 20-inch iron delivery tube of the retort is attached a 10-inch glass tube, and between the cover and the retort is placed a paper gasket cut from heavy wrapping-paper. The material is rapidly distilled to a dry coke from which no further distillate can be obtained, not over 25 minutes being allowed from the time of placing flame under retort until distillation ceases. About 5 grams of the distillate are taken if the materials contain 2 per cent or less of paraffine and about 3 grams if the material contains over 2 per cent of paraffine. This amount of distillate is dissolved in 25 cc. of Squibbs Absolute Ether in a 2-ounce glass flask, after which 25 cc. of Squibbs Absolute Alcohol are added. A one-to-one wash of 25 cc. each of similar ether and alcohol is made up, and the solution of oil and the wash are then frozen separately for 40 minutes in a salt and ice mixture, giving a temperature of 0° F. The precipitate is filtered quickly by means of a suction pump by using a No. 575 C. S. & S. 9-centimeter hardened filter-paper; the paper being placed in a funnel packed in a freezing mixture of salt and ice. The paraffine caught on the filter-paper is washed with the cool one-to-one wash until the paraffine is white. The paraffine is then scraped into a weighted crystallizing dish and maintained at a temperature of 212° F. until a constant weight is obtained, after which it is weighed and the percentage of paraffine in the original material is computed by dividing the weight of the paraffine obtained by the number of grams of distillate taken for freezing, and multiply this result by the percentage distilled from the original sample (i.e., by 100 per cent less weight of coke expressed in percentage). The paraffine so determined to have a melting point of at least 120° F.

The melting-point of paraffine is determined by covering the bulb of a thermometer with the paraffine; suspending the thermometer in a beaker of water at 65° F., and heating the water at the rate of

8° to 10° F. per minute. The temperature recorded by the thermometer at the time the paraffine melts from the bulb is taken as the melting-point of the paraffine.

Distillation of Tar. The distillation test of tar is made by measuring 100 cubic centimeters of the tar into a 250 cc. Engler distilling flask with delivery tube at the middle of the neck. The thermometer is so placed that the mercury bulb is opposite the outlet of the flask. The thermometer used to have a nitrogen chamber to insure accurate reading at high temperatures. The flame is so regulated that approximately 1 cc. of distillate is caught per minute. The distillation is made continuous.

The following fractions should be reported:

Start of distillation to 110° C.
110° C. " 170° C.
170° C. " 235° C.
235° C. " 270° C.
270° C. " 300° C.
Residue (pitch)

Fixed Carbon and Mineral Matter. The fixed carbon is determined by weighing approximately 1 gram of the material into a weighed platinum crucible with a tightly fitting cover. The crucible, with its cover in place, is then placed about 4 inches over a freely burning Bunsen Burner so as to be completely enveloped in the flame and exposed to the full heat of the burner for about 3 minutes or until the top of the crucible cover is burned free from the carbon; the under side of the cover being covered with the carbon. The flame is then withdrawn, the crucible cooled and weighed. The weight after burning, less the weight of the crucible, gives the amount of fixed carbon plus the mineral matter. The fixed carbon is then burned off in the open crucible until a constant weight is obtained; the crucible cooled and weighed. This weight is the crucible plus the mineral matter. The mineral matter subtracted from the combined weight of fixed carbon and mineral matter gives the fixed carbon.

Items 64 to 74 Inclusive — Bituminous Materials

64.1. Under items 64 to 74 inclusive the Contractor shall furnish and deliver on the work at such points as the Engineer may direct, bituminous material of the kind shown on the proposal sheet as to be furnished under its respective item.

64.2. Bituminous material furnished shall be of approved quality and shall meet the requirements specified below for the kind of material furnished, and for any contract, the material furnished shall be of one brand and shall show a uniform test unless special permission is given to furnish other brands of material.

64.3. The quantity to be paid for under this item shall be the number of gallons delivered on the work, unless the material is to be incorporated in the work by the same Contractor, and under the same contract.

If the material is to be incorporated in the work by the same Contractor, and under the same contract, the quantity to be paid for under this item shall be the number of gallons incorporated in the work under directions of the Engineer.

Bituminous material that has been rendered unfit for use by overheating or by long-continued heating, shall not be paid for. For purposes of measurement, a gallon shall be a volume of 231 cubic inches and measurement shall be based on the volume of the bituminous material of a temperature of 60 degrees Fahrenheit.

The price bid when the material is not to be incorporated in the work under this contract, shall include the furnishing of the material along the road as directed by the Engineer. Any material wasted through careless handling will not be paid for.

The price bid shall include the furnishing of the bituminous material alongside the road at places designated by the Engineer. Where the material delivered is to be incorporated into the work under this contract, the cost of manipulating and incorporating this material shall be included in the price bid for the top course of the pavement being constructed.

Item 64 — Specification for Bituminous Material A

Mixing Method (Type 1)

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) The various hydrocarbons composing it shall be present in a homogeneous solution.

(3) It shall have a specific gravity at 77 degrees Fahrenheit of not less than 0.97.

(4) The penetration shall be between 8 and 12 millimeters when tested for 5 seconds at 77 degrees Fahrenheit with a No. 2 needle, weighted with 100 grams.

(5) Fifty grams of it upon being maintained at a uniform temperature of 325 degrees Fahrenheit for 5 hours in a cylindrical vessel $5\frac{1}{2}$ centimeters in diameter by $3\frac{1}{2}$ centimeters high shall not lose more than 4 per centum in weight. The penetration (5 seconds, 77 degrees Fahrenheit, No. 2 needle, 100 grams weight) of this residue shall be at least 50 per centum of the original penetration.

(6) Its solubility at air temperature in chemically pure carbon disulphide for the following named materials, or materials similar thereto, shall be at least 99.5 per centum for pure bitumen products, 96 per centum for Bermudez products, 81 per centum for Cuban products and 66 per centum for Trinidad products.

(7) The solubility of the bitumen at air temperature, in 76 degrees Beaumé paraffine petroleum naphtha distilling between 140 degrees and 190 degrees Fahrenheit, shall be between 68 and 88 per centum.

(8) The bitumen shall show between 8 and 17 per centum fixed carbon.

(9) It shall show an open flash point not less than 375 degrees Fahrenheit.

(10) It shall not contain more than 4.7 per centum paraffine scale.

(11) It shall show a toughness at 32 degrees Fahrenheit not less than 10 centimeters. Toughness is determined by breaking a cylinder of the material $1\frac{3}{4}$ inches in diameter by $1\frac{3}{4}$ inches in height in a Page impact machine. (American Society of Testing Materials, August 15, 1908.) The first drop of the hammer is from a height of 5 centimeters and each succeeding blow is increased by 5 centimeters.

(12) It shall have a ductility at 77 degrees Fahrenheit of not less than 25 centimeters (Dow mould).

(13) All bituminous material A. will be sampled by an Engineer of the Department of Highways and samples sent to the Bureau of Tests, Albany, N. Y.

Item 65 — Specification for Bituminous Material A

Mixing Method (Type No. 2)

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) The various hydrocarbons composing it shall be present in a homogeneous solution.

(3) It shall have a specific gravity at 77 degrees Fahrenheit of not less than 0.97.

(4) The penetration shall be between 6 and 8 millimeters when tested for 5 seconds at 77 degrees Fahrenheit with a No. 2 needle, weighted with 100 grams.

(5) Fifty grams of it being upon maintained at a uniform temperature of 325 degrees Fahrenheit for 5 hours in a cylindrical vessel, $5\frac{1}{2}$ centimeters in diameter by $3\frac{1}{2}$ centimeters high shall not lose more than 4 per centum in weight. The penetration (5 seconds, 77 degrees Fahrenheit, No. 2 needle, 100 grams weight) of this residue shall be at least 50 per centum of the original penetration.

(6) Its solubility at air temperature in chemically pure carbon disulphide for the following named materials, or materials similar thereto, shall be at least 99.5 per centum for pure bitumen products, 96 per centum for Bermudez products, 81 per centum for Cuban products and 66 per centum for Trinidad products.

(7) The solubility of the bitumen at air temperature, in 76 degrees Beaumé paraffine petroleum naphtha distilling between 140 degrees and 190 degrees Fahrenheit shall be between 68 and 88 per centum.

(8) The bitumen shall show between 8 and 17 per centum fixed carbon.

(9) It shall show an open flash point not less than 375 degrees Fahrenheit.

(10) It shall not contain more than 4.7 per centum paraffine scale.

(11) It shall show a toughness at 32 degrees Fahrenheit not less than 5 centimeters. Toughness is determined by breaking a cylinder of the material $1\frac{3}{4}$ inches in diameter by $1\frac{3}{4}$ inches in height in a Page impact machine. (American Society of Testing Materials, August 15, 1908.) The first drop of the hammer is from a height of 5 centimeters and each succeeding blow is increased by 5 centimeters.

(12) It shall have a ductility at 77 degrees Fahrenheit of not less than 25 centimeters (Dow mould).

(13) All bituminous material A. will be sampled by an Engineer of the Department of Highways and samples sent to the Bureau of Tests, Albany, N. Y.

Item 66 — Specification for Bituminous Material A

Penetration Method

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) The various hydrocarbons composing it shall be present in a homogeneous solution.

(3) It shall have a specific gravity at 77 degrees Fahrenheit of not less than 0.97.

(4) The penetration shall be between 14 and 19 millimeters when tested for 5 seconds at 77 degrees Fahrenheit with a No. 2 needle, weighted with 100 grams.

(5) Fifty grams of it upon being maintained at a uniform temperature of 325 degrees Fahrenheit for 5 hours in a cylindrical vessel $5\frac{1}{2}$ centimeters in diameter by $3\frac{1}{2}$ centimeters high shall not lose more than 5 per centum in weight. The penetration (5 seconds, 77 degrees Fahrenheit, No. 2 needle, 100 grams weight) of this residue shall be at least 50 per centum of the original penetration.

(6) Its solubility at air temperature in chemically pure carbon disulphide for the following named materials, or materials similar thereto, shall be at least 99.5 per centum for pure bitumen products, 96 per centum for Bermudez products, 81 per centum for Cuban products and 66 per centum for Trinidad products.

(7) The solubility of the bitumen at air temperature, in 76 degrees Beaumé paraffine petroleum naphtha distilling between 140 degrees and 190 degrees Fahrenheit shall be between 70 and 88 per centum.

(8) The bitumen shall show between 8 and 16 per centum fixed carbon.

(9) It shall show an open flash point not less than 375 degrees Fahrenheit.

(10) It shall not contain more than 4.7 per centum paraffine scale.

(11) It shall show a toughness at 32 degrees Fahrenheit not less than 15 centimeters. Toughness is determined by breaking a cylinder of the material $1\frac{1}{4}$ inches in diameter by $1\frac{3}{4}$ inches in height, in a Page impact machine. (American Society of Testing Materials August 15, 1908.) The first drop of the hammer is from a height of 5 centimeters and each succeeding blow is increased by 5 centimeters.

(12) It shall have a ductility at 77 degrees Fahrenheit of not less than 40 centimeters (Dow mould).

(13) All bituminous material A. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N.Y.

Item 67 — Specification for Bituminous Material H. O.

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) The various hydrocarbons composing it shall be present in a homogeneous solution.

(3) It shall have a specific gravity at 77 degrees Fahrenheit of not less than 0.96.

(4) When evaporated in the open air at a temperature not exceeding 500 degrees Fahrenheit until the residue remaining has a penetration (5 seconds, 77 degrees Fahrenheit, No. 2 needle, 100 grams weight) of 10 millimeters the amount of such residue shall not be less than 85 per centum nor more than 95 per centum of the original oil. At a temperature of 77 degrees Fahrenheit such residue shall have a ductility of at least 25 centimeters (Dow mould).

(5) Fifty grams of it upon being maintained at a uniform temperature of 325 degrees Fahrenheit for five hours, in a cylindrical vessel $5\frac{1}{2}$ centimeters in diameter by $3\frac{1}{2}$ centimeters high, shall not lose more than 10 per centum in weight.

(6) It shall be soluble in chemically pure carbon disulphide at air temperature to the extent of at least 99.5 per centum.

(7) It shall be soluble at air temperature in 76 degrees Beaumé paraffine petroleum naphtha distilling between 140 degrees and 190 degrees Fahrenheit to the extent of not less than 75 per centum and not more than 90 per centum.

(8) It shall show between 6 and 14 per centum of fixed carbon.

(9) It shall show an open flash point of not less than 325 degrees Fahrenheit.

(10) It shall not contain more than 4.7 per centum paraffine scale.

(11) It shall show a toughness at 32 degrees Fahrenheit not less than 20 centimeters. Toughness is determined by breaking a cylinder of the material $1\frac{3}{4}$ inches in diameter by $1\frac{3}{4}$ inches in height in a Page impact machine. (American Society of Testing Materials, August 15, 1908.) The first drop of the hammer is from a height of 5 centimeters and each succeeding blow is increased by 5 centimeters.

(12) All bituminous material H. O. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N. Y.

Item 68 — Specification for Bituminous Material C. O.

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) The various hydrocarbons composing it shall be present in a homogeneous solution.

(3) It shall have a specific gravity at 77 degrees Fahrenheit of not less than 0.93.

(4) When evaporated in the open air at a temperature not exceeding 500 degrees Fahrenheit until the residue remaining has a penetration (5 seconds, 77 degrees Fahrenheit, No. 2 needle, 100 grams weight) of 10 millimeters the amount of residue shall not be less than 50 per centum nor more than 65 per centum of the original oil. At

a temperature of 77 degrees Fahrenheit such residue shall have a ductility of at least 25 centimeters (Dow mould).

(5) Fifty grams of it upon being maintained at a uniform temperature of 325 degrees Fahrenheit for five hours, in a cylindrical vessel $5\frac{1}{2}$ centimeters in diameter by $3\frac{1}{2}$ centimeters high, shall not lose more than 30 per centum in weight.

(6) It shall be soluble in chemically pure carbon disulphide at air temperature to the extent of at least 99.5 per centum.

(7) It shall be soluble at air temperature in 76 degrees Beaumé paraffine petroleum naphtha distilling between 140 and 190 degrees Fahrenheit to the extent of not less than 80 per centum and not more than 95 per centum.

(8) It shall not show more than 10 per centum fixed carbon.

(9) It shall show an open flash point of not less than 125 degrees Fahrenheit.

(10) It shall not contain more than 4.0 per centum paraffine scale.

(11) All bituminous material C. O. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N. Y.

Item 69 — Specification for Bituminous Material T

High Carbon — Binder

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) It shall be uniform in character, appearance and viscosity.

(3) It shall have a specific gravity of not less than 1.20 at 25 degrees centigrade.

(4) It shall contain not more than 25 per centum nor less than 12 per centum of free carbon.

(5) When distilled by the method of the American Society for Testing Materials, it shall contain no body that distills at a lower temperature than 170 degrees centigrade; not over 3 per centum shall distill below 235 degrees centigrade; not over 12 per centum shall distill below 270 degrees centigrade, and not over 16 per centum shall distill below 300 degrees centigrade. The specific gravity of the entire distillate shall not be less than 1.03 at 25 degrees centigrade. The residue from the foregoing distillation shall have a melting point not greater than 75 degrees centigrade ball and ring method.

(6) It shall have a melting point of not less than 27 degrees C., and not more than 34 degrees C., by ball and ring method.

(7) All bituminous material T. will be sampled by an Engineer of the Department of Highways and samples sent to the Bureau of Tests, Albany, N. Y.

Item 70 — Specification for Bituminous Material T

High Carbon — Hot Application

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) It shall be uniform in character, appearance and viscosity.

(3) It shall have a specific gravity not less than 1.19 at 25 degrees centigrade.

(4) It shall contain not more than 22 per centum nor less than 10 per centum of free carbon.

(5) When distilled by the method of the American Society for Testing Materials, it shall contain no body that distills at a lower temperature than 170 degrees centigrade, not over 10 per centum shall distill below 235 degrees centigrade; not over 16 per centum shall distill below 270 degrees centigrade and not over 20 per centum shall distill below 300 degrees centigrade. The specific gravity of the entire distillate shall not be less than 1.03 at 25 degrees centigrade. The residue from the foregoing distillation shall have a melting point not greater than 75 degrees centigrade ball and ring method.

(6) It shall have a float test (New York Testing Laboratory method) at 100 degrees centigrade between eighteen and twenty-eight seconds.

(7) All bituminous material T. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N. Y.

Item 71 — Specification for Bituminous Material T

High Carbon — Cold Application

This bituminous material shall have the following characteristics:

(1) It shall have a specific gravity of 1.14 to 1.18 at 25 degrees centigrade.

(2) It shall contain not more than 12 per centum nor less than 4 per centum of free carbon.

(3) When distilled by the method of the American Society for Testing Materials, not over 5 per centum shall distill below 170 degrees centigrade; not over 18 per centum shall distill below 235 degrees centigrade; not over 25 per centum shall distill below 270 degrees centigrade, and not over 32 per centum shall distill below 300 degrees centigrade. The specific gravity of the entire distillate shall not be less than 1.01 at 25 degrees centigrade. The residue from the foregoing distillation shall have a melting point not greater than 70 degrees centigrade ball and ring method.

(4) The viscosity when tested by the standard Engler viscosimeter shall not be more than 125 seconds at 60 degrees centigrade for the first 100 cubic centimeters.

(5) All bituminous material T. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N. Y.

Item 72 — Specification for Bituminous Material T

Low Carbon — Binder

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) It shall be uniform in character, appearance and viscosity.

(3) It shall have a specific gravity not less than 1.16 at 25 degrees centigrade.

(4) It shall contain not more than 5 per centum free carbon.

(5) When distilled by the method of the American Society for Testing Materials, it shall contain no body that distills at a lower temperature than 170 degrees centigrade; not over 5 per centum shall distill below 235 degrees centigrade; not over 15 per centum shall distill below 270 degrees centigrade; not over 20 per centum shall distill below 300 degrees centigrade. The residue from the foregoing distillation shall have a melting point not greater than 75 degrees centigrade ball and ring method.

(6) It shall have a melting point of not less than 27 degrees C., and not more than 34 degrees C., by ball and ring method.

(7) All bituminous material T. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N. Y.

Item 73 — Specification for Bituminous Material T

Low Carbon — Hot Application

This bituminous material shall have the following characteristics:

(1) It shall be free from water.

(2) It shall be uniform in character, appearance and viscosity.

(3) It shall have a specific gravity of not less than 1.14 at 25 degrees centigrade.

(4) It shall contain not more than 4 per centum of free carbon.

(5) When distilled by the method of the American Society for Testing Materials, not over 1 per centum shall distill below 170 degrees centigrade; not over 12 per centum shall distill below 235 degrees centigrade; not over 20 per centum shall distill below 270 degrees centigrade, and not over 25 per centum shall distill below 300 degrees centigrade. The residue from the foregoing distillation shall have a melting point not greater than 75 degrees centigrade ball and ring method.

(6) It shall have a float test (New York Testing Laboratory method) at 100 degrees centigrade between fifteen and twenty-five seconds.

(7) All bituminous material T. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Test, Albany, N. Y.

Item 74 — Specification for Bituminous Material T

Low Carbon — Cold Application

This bituminous material shall have the following characteristics:

(1) It shall have a specific gravity of 1.10 to 1.13 at 25 degrees centigrade.

(2) It shall contain not more than 2 per centum of free carbon.

(3) When distilled by the method of the American Society for Testing Materials, not over 5 per centum shall distill below 170 degrees centigrade; not over 20 per centum shall distill below 235 degrees centigrade; not over 28 per centum shall distill below 270 degrees centigrade, and not over 35 per centum shall distill below 300 degrees centigrade. The residue from the foregoing distilla-

tion shall have a melting point not greater than 70 degrees centigrade ball and ring method.

(4) The viscosity when tested by the standard Engler viscosimeter shall not be more than 125 seconds at 60 degrees centigrade for the first 100 cubic centimeters.

(5) All bituminous material T. will be sampled by an Engineer of the Department of Highways, and samples sent to the Bureau of Tests, Albany, N. Y.

BRICK

Paving brick shall be reasonably perfect in shape — shall be free from marked warping or distortion, and shall be uniform in size, so as to fit closely together and to make a smooth pavement. All brick shall be homogeneous in texture and free from laminations and seams. All brick shall be evenly burned and thoroughly vitrified.

Soft, brittle, cracked, or spalled brick, or brick kiln-marked to a height or depth of over $\frac{3}{64}$ parts of an inch will be rejected.

If brick have rounded corners, the radius shall not be greater than $\frac{1}{16}$ part of an inch.

Brick must have not less than two nor more than four vertical lugs or projections not more than $\frac{1}{2}$ inch wide, on one side of each brick, the total area of all lugs being not more than 3 square inches, so that when laid there shall be a separation between the bricks of at least $\frac{1}{8}$ inch and not more than $\frac{1}{4}$ inch. The imprint, or name of the brick, or maker, if used, shall be by means of recessed and not by raised letters. The two ends of the brick shall have a semi-circular groove, with a radius of not less than $\frac{1}{8}$ of an inch and not more than $\frac{1}{4}$ of an inch. Grooves shall be so located that when the brick are laid together the grooves shall match perfectly; grooves shall be horizontal when brick is laid in pavement.

All brick shall not be less than $3\frac{1}{4}'' \times 3\frac{3}{4}'' \times 8\frac{1}{2}''$ nor more than $3\frac{1}{2}'' \times 4'' \times 9''$ in size.

All brick shall be subject to tests for abrasion and impact, for absorption, according to the standard methods prescribed by the National Brick Manufacturers' Association, as follows:

THE RATTLER

The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame and driving mechanism as herein described.

THE BARREL

The barrel of the machine shall be made up of the heads, head-liners and staves.

The heads shall be cast with trunnions in one piece. The trunnion bearings shall not be less than two and one-half ($2\frac{1}{2}$) inches in diameter or less than six (6) inches in length.

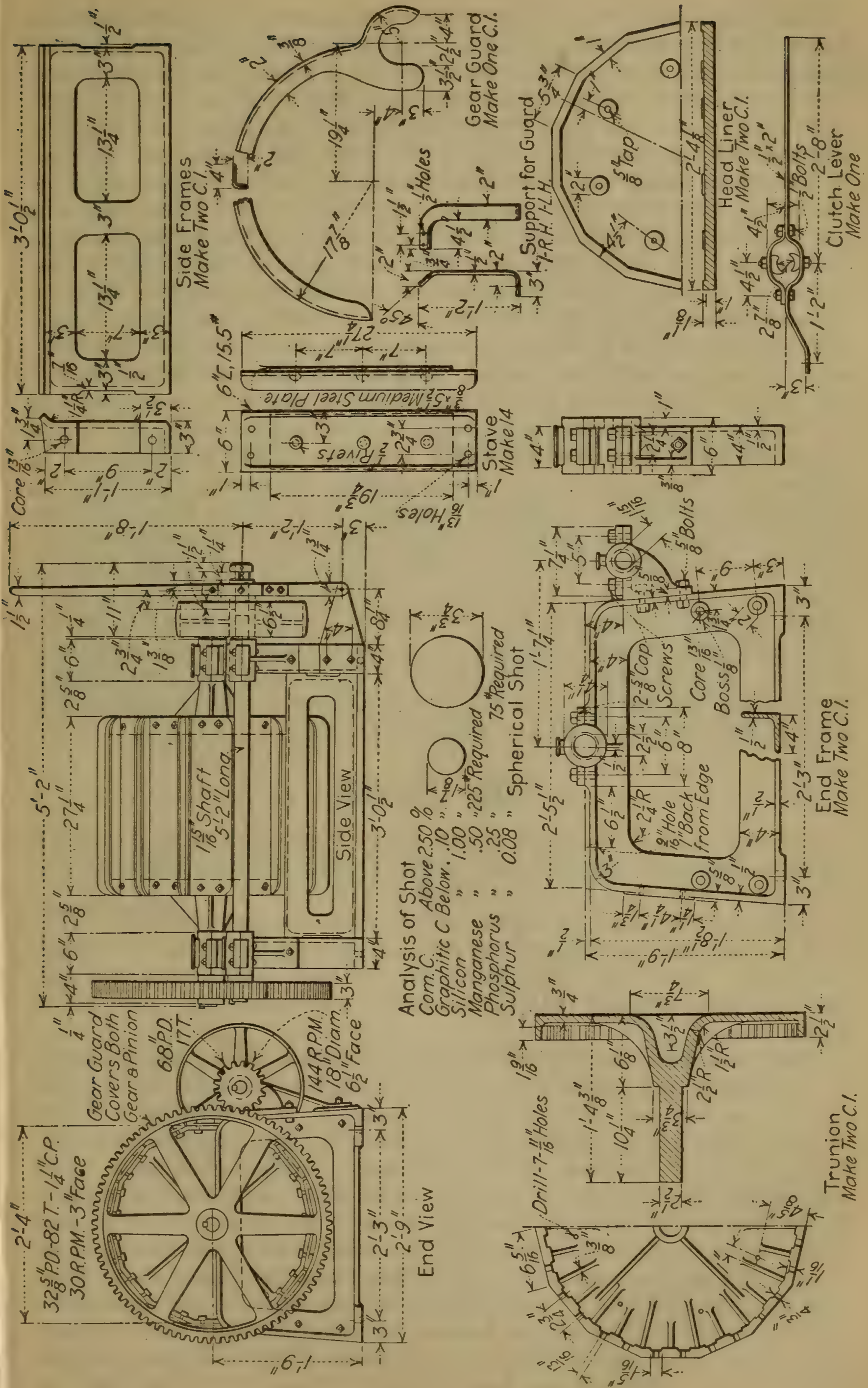

Side Frames Make Two C.I.
Gear Guard Make One C.I.
Support for Guard 1-R.H. 1-L.H.
Head Liner Make Two C.I.
Clutch Lever Make One
Stave Make 14
Medium Steel Plate
Rivets
Side View
Shaft 5'-2" Long
Spherical Shot
225 Required
75 Required
Analysis of Shot
Com. C. Above 2.50 %
Graphitic C Below .10
Silicon 1.00
Manganese .50
Phosphorus .25
Sulphur 0.08
End Frame Make Two C.I.
Cap Screws
Core
Boss
Hole Back from Edge
Bolts
Gear Guard Covers Both Gear & Pinion
68 P.D. 17 T.
144 R.P.M. 18" Diam. 6½" Face
32⅝" P.D. 82 T. - 1¼" C.P. 30 R.P.M. - 3" Face
End View
Trunion Make Two C.I.
Drill - 7-11/16" Holes

FIG. 74 A

The heads shall not be less than three-fourths ($\frac{3}{4}$) inch thick nor more than seven-eighths ($\frac{7}{8}$) inch. In outline they shall be a regular fourteen-sided (14) polygon inscribed in a circle twenty-eight and three-eighths ($28\frac{3}{8}$) inches in diameter. The heads shall be provided with flanges not less than three-fourths ($\frac{3}{4}$) inch thick and extending outward two and one-half ($2\frac{1}{2}$) inches from the inside face of head to afford a means of fastening the staves. The flanges shall be slotted on the outer edge, so as to provide for two (2) three-fourths ($\frac{3}{4}$) inch bolts at each end of each stave, said slots to be thirteen-sixteenths ($\frac{13}{16}$) inch wide and two and three-fourths ($2\frac{3}{4}$) inches center to center. Under each section of the flanges there shall be a brace three-eighths ($\frac{3}{8}$) inch thick and extending down the outside of the head not less than two (2) inches. Each slot shall be provided with recess for bolt head, which shall act to prevent the turning of the same. There shall be for each head a cast-iron headliner one (1) inch in thickness and conforming to the outline of the head, but inscribed in a circle twenty-eight and one-eighth ($28\frac{1}{8}$) inches in diameter. This liner or wear plate shall be fastened to the head by seven (7) five-eighths ($\frac{5}{8}$) inch cap screws, through the head from the outside. These wear plates, whenever they become worn down one-half ($\frac{1}{2}$) inch below their initial surface level, at any point of their surface, must be replaced with new. The metal of which these wear plates are to be composed shall be what is known as hard machinery iron, and must contain not less than one (1) per cent of combined carbon. The faces of the polygon must be smooth and give uniform bearing for the staves. To secure the desired uniform bearing the faces of the head may be ground or machined.

THE STAVES

The staves shall be made of six (6) inch medium steel structural channels twenty-seven and one-fourth ($27\frac{1}{4}$) inches long and weighing fifteen and five-tenths (15.5) pounds per lineal foot.

The channels shall be drilled with holes thirteen-sixteenths ($\frac{13}{16}$) inch in diameter, two (2) in each end, for bolts to fasten same to head, the center line of the holes being one (1) inch from either end and one and three-eighths ($1\frac{3}{8}$) inches either way from the longitudinal center line.

The space between the staves will be determined by the accuracy of the heads, but must not exceed five-sixteenths ($\frac{5}{16}$) inch. The interior or flat side of each channel must be protected by a lining or wear plate three-eighths ($\frac{3}{8}$) inch thick by five and one-half ($5\frac{1}{2}$) inches wide by nineteen and three-fourths ($19\frac{3}{4}$) inches long. The wear plate shall consist of medium steel plate, and shall be riveted to the channel by three (3) one-half ($\frac{1}{2}$) inch rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced seven (7) inches from the center each way. The rivet holes shall be countersunk on the face of the wear plate and the rivets shall be driven hot and chipped off flush with the surface of the wear plate. These wear plates shall be inspected from time to time, and if found loose shall be at once reriveted, but no

wear plate shall be replaced by a new one except as the whole set is changed. No set of wear plates shall be used for more than one hundred and fifty (150) tests under any circumstances. The record must show the date when each set of wear plates goes into service and the number of tests made upon each set.

The staves when bolted to the heads shall form a barrel twenty (20) inches long, inside measurement, between wear plates. The wear plates of the staves must be so placed as to drop between the wear plates of the heads. These staves shall be bolted tightly to the heads by four (4) three-fourths ($\frac{3}{4}$) inch bolts, and each bolt shall be provided with lock nuts, and shall be inspected at not less frequent intervals than every fifth (5th) test and all nuts kept tight. A record shall be made after each such inspection, showing in what condition the bolts were found.

THE FRAME AND DRIVING MECHANISM

The barrel should be mounted on a cast-iron frame of sufficient strength and rigidity to support same without undue vibration. It should rest on a rigid foundation and be fastened to same by bolts at not less than four (4) points.

It should be driven by gearing whose ratio of driver to driven should not be less than one (1) to four (4). The counter shaft upon which the driving pinion is mounted should not be less than one and fifteen-sixteenths ($1\frac{15}{16}$) inches in diameter, with bearings not less than six (6) inches in length and belt driven, and the pulley should not be less than eighteen (18) inches in diameter and six and one-half ($6\frac{1}{2}$) inches in face. A belt of six (6) inch double-strength leather, properly adjusted, so as to avoid unnecessary slipping, should be used.

(As a part of this publication will be found a complete working drawing of a machine which will meet the above specifications and requirements.)

THE ABRASIVE CHARGE

(*a*) The abrasive charge shall consist of two sizes of cast-iron spheres. The larger size shall be three and seventy-five-hundredths (3.75) inches in diameter when new and shall weigh when new approximately seven and five-tenths (7.5) pounds (3.40 kilos) each. Ten shall be used.

These shall be weighed separately after each ten (10) tests, and if the weight of any large shot falls to seven (7) pounds (3.175 kilos) it shall be discarded and a new one substituted; provided, however, that all of the large shot shall not be discarded and substituted by new ones at any single time, and that so far as possible the large shots shall compose a graduated series in various stages of wear.

The smaller size spheres shall be when new one and eight hundred seventy-five-thousandths (1.875) inches in diameter and shall weigh not to exceed ninety-five-hundredths (.95) pounds (0.430 kilos) each. Of these spheres so many shall be used as will bring the collective

weight of the large and small spheres most nearly to three hundred (300) pounds, provided that no small sphere shall be retained in use after it has been worn down so that it will pass a circular hole one and seventy-five-hundredths (1.75) inches in diameter, drilled in a cast-iron plate one-fourth ($\frac{1}{4}$) inch in thickness or weigh less than seventy-five-hundredths (.75) pounds (or .34 kilos). Further, the small spheres shall be tested by passing them over such an iron plate drilled with such holes, or shall be weighed after every ten (10) tests, and any which pass through or fall below specified weight, shall be replaced by new spheres, and provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

(b) The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon — Not less than 2.50%.
Graphitic carbon — Not more than 0.10%.
Silicon — Not more than 1%.
Manganese — Not more than 0.50%.
Phosphorus — Not more than 0.25%.
Sulphur — Not more than 0.08%.

For each new batch of spheres used the chemical analysis must be furnished by the maker, or be obtained by the user, before introduction into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

THE BRICK CHARGE

The number of brick per charge shall be ten (10) for all bricks of the so-called "block size" whose dimensions fall between from eight (8) to nine (9) inches in length, three (3) and three and three-fourths ($3\frac{3}{4}$) inches in breadth and three and three-fourths ($3\frac{3}{4}$) and four and one-fourth ($4\frac{1}{4}$) inches in thickness. No block should be selected for test that would be rejected by any other requirements for the specifications.

The brick shall be clean and dried for at least three (3) hours in a temperature of one hundred (100) degrees Fahr. before testing.

SPEED AND DURATION OF REVOLUTION

The rattler shall be rotated at a uniform rate of not less than twenty-nine and one-half ($29\frac{1}{2}$) nor more than thirty and one-half ($30\frac{1}{2}$) revolutions per minute, and eighteen hundred (1,800) revolutions shall constitute the standard test.

A counting machine shall be attached to the rattler for counting the revolutions. A margin of not to exceed ten (10) revolutions will be allowed for stopping. Only one (1) start and stop per test is regular and acceptable.

THE RESULTS

The loss shall be calculated in percentage of the original weight of the dried brick composing the charge. In weighing the rattled brick any piece weighing less than one (1) pound shall be rejected.

RECORDS

(*a*) The operator shall keep an official book, in which the alternate pages are perforated for removal. The record shall be kept in duplicate, by use of a carbon paper between the first and second sheets,

REPORT OF

Standard Rattler Test of Paving Bricks

Identification Data Serial No. ( )

Name of the firm furnishing sample

Name of the firm manufacturing sample

Street or job which sample represents

Brands or marks on the brick

Quantity furnished Drying treatment

Date received Date tested

Length Breadth Thickness

Standardization Data

Number of charges tested since last inspection

Weight of Charge (After Standardization)	Condition of Locknuts on Staves	Condition of Scales
10 Large spheres		
Small spheres		
Total		

Number of charges tested since stave linings were renewed

Repairs (Note any repairs affecting the condition of the barrel)

Running Data

Time Readings				Revolution Counter Readings	Running Notes, Stops, Etc.
	Hours	Minutes	Seconds		
Beginning of test					
Final Reading					

Weights and Calculations

		Percentage Loss (Note.—The Calculation Must Appear)
Initial Weight of 10 Bricks . . .		
Final Weight of Same		
Loss of Weight		

Number of broken bricks and remarks on same

I certify that the foregoing test was made under the specifications

of and is a true record.

Signature of (Tester) ______________________

Date Location of Laboratory

FIG. 74 B

and when all entries are made and calculations are completed the original record shall be removed and the carbon duplicate preserved in the book. All calculations must be made in the space left for that purpose in the record blank, and the actual figures must appear. The record must bear its serial number and be filled out completely for each test, and all data as to dates of inspection and weighing of shot and replacement of worn-out parts must be carefully entered, so that the records remaining in the book constitute a continuous one. In event of further copies of a record being needed, they may be furnished on separate sheets, but in no case shall the original carbon copy be removed from the record book.

(*b*) The blank form upon which the record of all official brick tests is to be kept and reported is shown in Fig. 74B.

Any brick which loses twenty-four (24) per cent or more in the rattler, or increases more than $3\frac{1}{2}$ per cent in weight or less than $\frac{1}{2}$ of 1 per cent in the absorption test, will be rejected.

HILLSIDE BRICK

On grades of five (5%) per cent or over the engineer may, if he deems advisable for the traffic, order the contractor to use special form of brick suitable for steep grades.

Expansion Joint Paving Pitch. This cushion shall be composed of heavy pitch or asphaltum composition, having a melting point of not less than 120° F. nor more than 140° F., filling the allotted space.

PREMOLDED EXPANSION JOINT

The expansion joints shall be composed of a high grade asphalt, that shall pass the following tests:

Specific gravity at 77° F., .98 to 1.05.
Melting point, ball and ring method, 220° to 250° F.
Loss on heating for 5 hours at 325° F., not over 1%.
Bitumen soluble in carbon disulphide, at least 98.5%.
Bitumen soluble in carbon tetrachloride, at least 99.8%.
Bitumen soluble in 76° Beaumé naphtha, 50 to 75%.
Penetration at 32° F. 200 grams, 1 min., at least 12.
Penetration at 77° F. 100 grams. 5 sec. between 15 and 35.
Penetration at 115° F. 50 grams, 5 sec. not more than 45.

BLOCK STONE PAVEMENT

(City of Rochester, N. Y., Specifications, 1911)

Paving blocks shall consist of the best quality of Medina sandstone free from quarry checks or cracks, and shall be quarried from fine-grain live rock, showing a straight and even fracture. The material shall be of uniform quality and texture, free from seams or lines of clay or other substances which, in the opinion of the City Engineer, will be injurious to its use as paving material.

Blocks shall measure not less than three (3) nor more than six (6) inches thick, and not less than six (6) nor more than six and one-half ($6\frac{1}{2}$) inches deep, and from seven (7) to twelve (12) inches in length. Stones to have parallel sides and ends, and right-angle joints. All roughness in joints of stone to be broken off, so that when set in place they shall have tight joints for a distance of at least two and one-half ($2\frac{1}{2}$) inches from the top down. The top to have a smooth even surface, with no projection or depression exceeding one-quarter ($\frac{1}{4}$) inch.

When approved by the City Engineer, paving blocks of the following dimensions may be used.

Three to five inches in width; five inches in depth, with an allowable variation of one-quarter inch, more or less, in said depth, and seven to twelve inches in length.

Paving blocks as here referred to shall be understood to mean blocks of Medina sandstone, prepared in the usual manner for dressed block paving by nicking and breaking the stone from larger blocks, as is done at the quarries where such blocks are usually prepared, and not made by re-dressing or selecting from common stone paving material.

The stones will be carefully inspected after they are brought on the line of the work, and the blocks which, in quality and dimensions, do not conform strictly to these specifications, will be rejected and must be immediately removed from the line of the work. The contractor will be required to furnish such laborers as may be necessary to aid the inspector in the examination and the culling of the blocks.

The stones brought upon the ground having been carefully and thoroughly inspected, as provided for herein, and all rejected stones removed from the line of the work, the contractor will then be required to pile such stone as may have been approved, neatly, on the front of the sidewalk, and not within three (3) feet of any fire hydrant, and in such manner as will preserve sufficient passageway, on the line of the sidewalks, and also permit of free access from the roadway to each entrance on the line of the street.

SECOND QUALITY BLOCKS

(THE FOLLOWING NOT IN ANY SPECIFICATIONS)

Second quality block, known as pavers, are practically the same material as the first quality block, the only difference being a greater range of size and a less careful top and joint finish. They cost \$0.50 per square yard less. These pavers can be furnished under a specification allowing the following range of size and joint width:

(CITY OF CLEVELAND SPECIFICATIONS)

"Common paving stones shall consist of the best quality of Medina sandstone, and shall be not less than three (3) nor more than five (5) inches thick, and not less than seven (7) nor more than eight (8) inches deep, and from eight (8) to thirteen (13) inches long. The stones to have parallel sides and ends, with right-angle joints, all

roughness and points of stone to be broken off so that when set in place they shall have tight joints for a distance of at least three inches from the top; the area of the bottom of any stone to be not less than three-quarters ($\frac{3}{4}$) of the area of the top, the top of all stones to have a smooth even surface."

CAST-IRON PIPE

Cast-iron pipe shall be light weight and may be second quality, but it shall be free from all defects impairing its strength. The iron must be of good quality, uniform in thickness and of full strength, and the pipe shall be coated with coal pitch varnish mixed with linseed oil to form a firm, tough coating. The joint shall be formed by calking into the hub a gasket of jute or oakum and then filling with mortar formed of equal parts of Portland Cement and clean sharp sand.

MESH REINFORCEMENT

Mesh reinforcement shall be placed where called for on the plans or ordered by the engineer. It shall be of medium steel.

If expanded metal is used it shall conform to the above requirements, and the weight per square foot shall be as shown on the standard structure sheet, and any reinforcement shall be of a character that it will distribute the loads evenly.

DEFORMED BARS

Deformed bars shall be placed where called for on the plans or ordered by the engineer. They shall be of medium steel and shall have a deformed cross-section, that is, the various cross-sections must be of different shape or their centers must not lie in the same axis.

CAST IRON

Cast iron shall be of full standard pattern for shapes or forms used, according to drawings or detailed specifications. All cast iron shall be of good gray iron, free from blows, sand holes, or other defects, and shall have a tensile strength of not less than 17,000 pounds per square inch of section.

WROUGHT IRON

Wrought iron shall be tough, fibrous, and uniform in quality and shall be manufactured by approved methods. Steel scrap shall not be used in its manufacture. Finished material shall be clean, smooth, straight, true to shape, of workmanlike finish and free from defects.

Test pieces cut from finished material shall show an ultimate tensile strength of not less than 48,000 pounds per square inch, an elastic limit of not less than 25,000 pounds per square inch, and an elongation of not less than 20 per cent in 8 inches.

Wrought-iron test pieces cut from finished material when cold, or when heated to a bright, cherry-red, shall endure bending 180 degrees around a circle whose diameter is equal to twice the thickness of the test piece, without signs of cracking. Test pieces when nicked and broken shall show a fracture not less than 90 per cent fibrous, free from coarse, crystalline spots.

Wrought iron when welded shall not show signs of red shortness.

STEEL

(1) Steel, except as otherwise provided by these specifications, shall be made by the acid or basic open-hearth process and shall be uniform in character; finished material shall be clean, smooth, straight, true to shape, of workmanlike finish, and free from defects.

(2) Fractures must show a uniform fine grain of a blue, steel-gray color entirely free from a fiery luster or a blackish cast.

(3) No work shall be put upon any steel at or near the blue temperature or between the temperature of boiling water and of the ignition of hardwood sawdust.

(4) No sharp or unfilleted corners will be allowed in any piece of metal.

(5) **Annealing.** Crimped stiffeners and buckled plates need not be annealed. All other steel that has been bent cold or partially heated and all forgings must be wholly annealed; exception may be made in unimportant cases and then only upon written permission from the Commission.

(6) Tests of steel that is to be annealed shall be made after annealing, or strips cut from such steel shall be annealed at the same time, before testing.

(7) **Tests of Medium Steel.** Test pieces cut from finished material shall show an ultimate strength of not less than sixty thousand (60,000) pounds per square inch and not more than sixty-eight thousand (68,000) pounds per square inch, an elastic limit of not less than thirty-five thousand (35,000) pounds per square inch, an elongation of not less than twenty-two (22) per cent in eight (8) inches, and a reduction of area at the fracture of not less than forty (40) per cent.

(8) Medium steel shall not contain more than five one-hundredths (5–100) of one per cent of sulphur.

(9) Acid steel shall not contain more than eight one-hundredths (8–100) of one per cent, and basic steel shall not contain more than four one-hundredths (4–100) of one per cent of phosphorus.

(10) Medium steel shall endure bending cold or after quenching from a red heat in water at 80° F., 180° around a circle whose diameter is equal to the thickness of the test piece, without signs of cracking.

(11) **Tests for Soft Steel.** Test pieces cut from finished material shall show an ultimate strength of not less than fifty thousand (50,000) pounds per square inch and not more than fifty-eight thousand (58,000) pounds per square inch, an elastic limit of not less than thirty thousand (30,000) pounds per square inch, an elongation

of not less than twenty-eight per cent in eight inches, and a reduction in area at the fracture of not less than fifty (50) per cent.

(12) Soft steel shall not contain more than four one-hundredths (4–100) of one per cent of sulphur.

(13) Acid steel shall not contain more than six one-hundredths (6–100) of one per cent, and basic steel shall not contain more than four one-hundredths (4–100) of one per cent of phosphorus.

(14) Soft steel shall endure bending flat upon itself without signs of cracking, when cold, or after quenching, from a red heat, in water at eighty (80) degrees F.

VITRIFIED PIPE

Vitrified pipe shall be double strength salt-glazed vitrified stoneware sewer pipe of the first quality. The item will include the furnishing, delivering, handling, laying, and cementing of joints; also the operations of excavating the trench, bracing, sheeting, or otherwise supporting the sides, grading and preparing the bottom, backfilling and compacting to the original surface, and the removal of all surplus material.

POROUS TILE

Where called for on the plans, or ordered by the engineer, porous tile shall be laid true to line and grade, and firmly bedded in clean cinders, gravel, or crushed stone. The tile must be whole and free from cracks and other defects, and must be satisfactory to the engineer.

TIMBER

(Washington State Specifications)

Quality of Timber and Plank. All timber and plank in culverts, trestlework, bridge abutments, and pile bridges shall be of good quality, of such kinds as the highway commissioner may direct, free from shakes, wanes, black and unsound knots, and all descriptions of decay, and shall be measured by the thousand feet, board measure; the price shall be understood to cover the expense of all labor (including all necessary digging and filling at the ends of bridges where grading is done before bridges are put in) and materials, pins, or treenails required in the performance of the work.

All timber structures shall be built in conformity with plans to be furnished by the engineer.

Piles and Pile-driving. Piles, whether used in foundations, trestlework, or pile bridges, shall be of good, sound quality of such timber as the Highway Commissioner may accept, not less than ten inches in diameter at the smaller end and of such lengths as the engineer may require. They shall be measured by the lineal foot after they are driven and cut off to receive the superstructure, and the price per lineal foot shall be understood to cover the expense of driving, cutting off, removing the bark from the part above the ground, and all other labor and material required in the performance

of the work; but that portion of each pile cut off shall be estimated and paid for by the lineal foot as "piling cut off." Piles shall be driven of such lengths and to such depths as the engineer may require. All piles shall be capped during the driving to prevent brooming.

CLEARING AND GRUBBING

Clearing. The right-of-way must be cleared to the width of —— feet on each side of the center line, or as shall be designated by the engineer; all trees, brush, and other vegetable matter within the space designated to be cut down, and the same, together with all other logs, brushwood, and fences already down, shall be burned or removed from the grounds, as the engineer may direct, so as not to injure the adjoining lands or to obstruct the line of the fences along the boundaries of the said right-of-way. When the embankments exceed two feet in height it will be required to cut the trees, brush, and stumps close to the ground.

Light clearing shall include the removal of all standing trees of a size up to one foot in diameter, together with all other logs, brush, and other vegetable matter already down or lying loose on the ground.

Heavy clearing shall include the removal of all standing trees over one foot in diameter, together with all other logs, brush, and other vegetable matter already down or lying loose on the ground.

Grubbing. From the space required for the roadbed and necessary slopes and side drains, and whatever additional space may be required by the engineer, except where the excavations are three feet or more in depth, or embankments two feet or more in height, all stumps and other wood or vegetable matter embedded in the ground shall be grubbed up, and removed or disposed of as the engineer may direct, and only the area so grubbed shall be estimated.

EXCAVATION

Under the head of excavation shall be included all excavations required for the formation of the road-bed, the digging of all ditches, cutting new channels for streams, preparing foundations, the altering of all highway or private roads and all excavations in any way connected with or incidental to the construction of the road, and the expense of hauling and depositing same in embankments wherever required.

Embankments. Under the head of embankments shall be included all embankments for any of the purposes mentioned not formed from excavations taken from the prism of the road or other necessary excavations.

All grading shall be done and estimated by the cubic yard, measured in the excavation, except material borrowed for embankment, which shall be measured in embankment, and shall be comprised under heads, viz.:

Earth, Hard-pan, Loose Rock, Solid Rock, Shell Rock, and Solid Rock Borrow.

Earth. Earth will include clay, sand, loam, gravel, and all hard material that can, in the opinion of the chief engineer, be reasonably plowed, and all earthy matter or earth containing loose stones or boulders intermixed, and all other material that does not come under the classification of hard-pan, loose rock, solid rock, shell rock, and solid rock borrow.

Hard-pan. Hard-pan will include material, not loose or solid rock, that cannot, in the opinion of the chief engineer, be reasonably plowed on account of its own inherent hardness.

Loose Rock. Loose rock will include all stone and detached rock, found in separate masses, containing not less than one cubic foot, nor more than one-half cubic yard, and all slate or other rock, soft or loose enough to be removed without blasting, although blasting may occasionally be resorted to.

Solid Rock. Solid rock will include all rock in place, and boulders measuring one-half cubic yard and upwards, in removing which it is necessary to resort to drilling and blasting.

Shell-Rock Excavation. Shell-rock excavation will include all deposits composed entirely of rock in masses of less than one cubic foot which have broken off from the cliffs above the roadbed, but will only be estimated when in large deposits.

Solid Rock Borrow. Solid rock borrow shall consist of solid rock, according to above classification, excavated outside of the regular cross-sections of the cuts for the roadbed, and placed and measured in embankment.

EXCAVATION

Item 2 — Earth Excavation

Item 3 — Rock Excavation

2.1. Under these items the Contractor shall grade the entire length of roadway, ditches and side slopes to the required lines and grades; shall make all excavations for culverts, under-drains, catch basins, leaching basins, and other structures except posts; shall grade connecting public highways as directed and remove spongy material from the sub-grade to the depths required — all as shown on the plans or as directed by the Engineer.

This item includes the excavation, filling and rolling necessary to complete the road and all structures connected therewith except as noted above, and includes the removal of all objectionable material for the full width of the improvement except as noted under section 1.1, and the filling to the required grade with acceptable material of all areas originally below the required grade, or excavated below grade under orders of the Engineer.

Backfill for structures, old macadam excavated, and sod ordered removed from the site of a new embankment, shall be paid for as Earth Excavation.

2.2. All suitable materials from the excavation shall be used so far as practicable in making embankments, building up low places on the sub-grade or shoulders, and such other places as directed.

2.3. Surplus material shall be placed in embankments, shall be used for extending the shoulders or shall be deposited in spoil banks, as directed by the engineer. All surplus materials shall be removed and disposed of as directed by the Engineer before the sub-grade or shoulder rolling is completed and beofre any stone is placed on the roadway.

2.4. If there is not sufficient suitable material to complete the grading and to bring the sub-grade to the required height, the contractor shall borrow additional material from the sides of the roadway or from other borrow pits as directed by the engineer so that the established grade for the road, embankments, etc. will be secured. All borrow pits outside the highway shall be acquired by the Contractor at his own expense, and any borrow pits in or adjacent to the highway shall be left in a neat and satisfactory condition and shall be thoroughly drained.

2.5. The contractor shall remove boulders and all muck, quicksand, soft clay and spongy material which will not consolidate under the roller, from the sub-grade to a depth to be determined by the engineer, and refill the space with acceptable materials from the excavations, or with stone or gravel, as directed. If stone or gravel is used, the same will be paid for at the contract price bid for item "FOUNDATION COURSE." After all drains have been laid and the surface of the sub-grade has been properly shaped, it shall be thoroughly rolled and compacted with an approved self-propelled roller weighing not less than 10 tons. Water puddling shall be resorted to in case the soil requires it. Care shall be taken not to roll clay foundations too much, thus developing a plastic condition. All hollows and depressions which develop shall be filled with acceptable material, and the sub-grade shall again be rolled. This process of filling and rolling shall be repeated until no depressions develop. In places where the character of the material makes the use of such a roller impracticable, a lighter one may be permitted. The sub-grade shall not be muddy, or otherwise unsatisfactory when the foundation course is placed upon it. All culverts, ditches, and drains shall be satisfactorily completed to effectively drain the highway before the placing of any pavement will be permitted. The shoulders shall be rolled and left in a compact and satisfactory condition at the completion of the pavement.

2.6. Embankment shall be formed of suitable materials. If formed of stone, all reasonable precautions must be taken to ensure a solid embankment. The upper surface of the embankment shall be rolled and left in a satisfactory condition and approximately true to lines and grades. Large stone shall not project within 6 inches of the finished sub-grade, and all hollows and depressions shall be filled with the smaller stone from the excavation, with gravel or with other acceptable material. Stone in embankments shall not be used nearer than 6 inches to the surface of shoulders.

Where the filling is less than 2 feet in depth all vegetable matter shall be removed from the original surface. Where necessitated by the existing slope, the original surface shall be trenched or otherwise broken up before placing new embankment thereon.

Embankment shall be constructed in successive horizontal layers not exceeding 12 inches in thickness; when concrete is to be placed thereon, these layers shall not exceed 6 inches in thickness. Each layer shall extend across the entire fill and shall be thoroughly rolled and compacted by approved methods. If impracticable to use a heavy roller for this work a grooved roller shall be used.

2.7. At all intersecting public highways the contractor shall grade back to a sufficient distance with acceptable materials, as directed by the engineer so that a smooth riding and satisfactory junction will be produced.

2.8. The quantity of excavation to be paid for under items 2 and 3 shall be the number of cubic yards of material, measured in its original position, excavated and disposed of as directed by the Engineer, and the limits shall not exceed those shown upon the plans or fixed by the Engineer.

The price bid for EARTH EXCAVATION shall include the removal of all materials, as specified under section 2.1 — except as provided below for "ROCK EXCAVATION," — the placing of same in embankment or spoil, the rolling, compacting, grading and all other work incidental thereto.

No direct payment shall be made under ITEMS 2 or 3 for work in connection with contractor's plant, nor for his other requirements in carrying out the provisions of this contract, but compensation therefor shall be considered as having been included in the prices stipulated for the various items of the contract.

The price bid for ITEM 3 shall include the removal of all boulders of more than 13 cubic feet and all hard ledge rock and the placing of same in embankment or spoil if not used under other items of the contract, and rolling, compacting, grading and all other work incidental thereto. Boulders of less than 13 cubic feet, and all soft or disintegrated rock which can be removed with pick and shovel, shall not be paid for under ROCK EXCAVATION, but under "EARTH EXCAVATION." The price bid for the ITEMS shall include all labor, materials, supplies, and plant and incidentals necessary to complete the work.

Item 4 — Overhaul

4.1. If the haul on any material either from cuts or borrow pits made in accordance with directions from the Engineer exceeds 2,000 feet it shall be classified as overhaul.

For each 100 feet of haul greater than 2,000 feet the Contractor shall receive the price bid for Overhaul per cubic yard of all material so moved, measured in its original position.

The price bid shall include all labor, appliances, and incidentals necessary to complete the work.

Item 5 — Vitrified Clay Pipe

5.1. Under this item the Contractor shall furnish and place vitrified pipe where directed by the Engineer.

5.2. Pipe shall be first quality, double strength, salt glazed, sound, vitrified, stoneware sewer pipe with bell joints.

5.3. All pipe shall be laid true to line and grade with bells upstream, and shall have a full, firm and even bearing. The joints shall be filled with jute and mortar consisting of one part Portland cement and two parts sand.

5.4. The quantity to be paid for under this item shall be the number of linear feet of pipe incorporated in the work under the directions and to the satisfaction of the Engineer.

The price bid shall include the furnishing and laying and all materials and incidentals necessary thereto, except that all excavation in connection therewith will be paid for under ITEM "EXCAVATION."

Item 6 — Vitrified Clay Underdrains

6.1. Under this item the Contractor shall furnish and lay 6-inch salt glazed vitrified pipe wherever required for drainage.

6.2. The pipe shall be laid true to line and grade with the bells up grade. A strap of burlap at least 6 inches wide and long enough to reach around the pipe and lap at least 1 foot shall be wrapped around each joint of pipe to give double thickness on the top and to act as a strainer. The pipe shall be covered as laid with clean gravel or broken stone of No. 2 or No. 3 size placed around and above it to the surface of the sub-grade.

6.3. The amount to be paid for under this item shall be the number of linear feet of pipe furnished and incorporated in the work.

The price bid shall include all labor, materials, and incidentals necessary to complete the work, except that the necessary excavation will be paid for under item "EXCAVATION," and the necessary broken stone will be paid for under item "BROKEN STONE, LOOSE MEASUREMENT."

Item 7 — Porous Tile Underdrain

7.1. Under this item the Contractor shall furnish and lay 6-inch porous tile wherever required for drainage.

7.2. The tile must be whole and free from cracks and other defects, and must be satisfactory to the Engineer.

7.3. The tile shall be laid true to line and grade and shall be covered as laid with clean gravel or broken stone placed around and above it to the surface of the sub-grade.

7.4. The amount to be paid for under this item shall be the number of linear feet of pipe furnished and incorporated in the work.

The price bid shall include all labor, materials, and incidentals necessary to complete the work, except that the necessary excavation will be paid for under item "EXCAVATION," and the necessary broken stone will be paid for under item "BROKEN STONE, LOOSE MEASUREMENT."

Item 8 — Concrete Leaching Basins

8.1. Under this item the Contractor shall build at places indicated on the plan or ordered by the Engineer, concrete leaching basins of a type shown on the detail plans.

8.2. The concrete used in these basins shall be second-class concrete.

8.3. The grating shall be of cast iron of the quality specified in item "MISCELLANEOUS IRON AND STEEL."

8.4. For each basin completed, the Contractor shall receive the price bid.

The price bid shall include all concrete, stone, grating, and all material, labor and incidentals necessary to complete the work, except that the excavation will be paid for under item "EXCAVATION."

Item 9 — Vitrified Leaching Basins

9.1. Under this item the Contractor shall build at places indicated on the plans or ordered by the Engineer, leaching basins of a type shown on the detail plans.

9.2. Vitrified pipe shall be of double thickness, sound, and thoroughly tamped in place.

9.3. The broken stone used for filling shall be No. 4 broken stone or gravel.

9.4. The grating shall be of cast iron of the quality specified in item "MISCELLANEOUS IRON AND STEEL."

9.5. For each basin completed in accordance with plans and under orders of the Engineer, the Contractor shall receive the price bid.

The price bid shall include all materials, labor and appliances, and all expenses incidental to completing the work, except the excavation — which last will be paid for under item "EXCAVATION."

Item 10 — Catch Basins

10.1. Under this item the Contractor shall build catch basins as shown on the plans, as directed by the Engineer.

10.2. The catch basins may be built of second-class concrete or of acceptable brick at the option of the Contractor. If bricks are used they shall be sound, hard burned brick of acceptable quality, and shall be laid by a competent mason and in a workmanlike manner. Mortar of one part Portland cement and two parts sand shall be used.

10.3. For each catch basin complete with cast iron top, as shown on plans and ordered by the Engineer, the Contractor shall receive the price bid.

The price bid shall include all labor, materials and incidentals required to complete each basin, except that the excavation will be paid for under item "EXCAVATION."

DROP INLETS

Drop inlets shall be constructed where shown upon the plans, or directed by the Engineer. The details of construction shall be such as he may direct.

Payment for drop inlets will be made under appropriate items at the contract price for the materials entering into their construction; that is, payment will be made for the various amounts of excava-

tion, concrete, cast iron, cast-iron pipe, etc. Payment under these items shall include all labor and materials necessary to complete the work.

Item 11 — Changing Elevation of Manholes and Catch Basins

11.1. Under this item the Contractor shall raise or lower to the grades given all existing covers of catch basins or manholes.

11.2. All changes shall be made with acceptable brick laid in Portland cement mortar of one part cement and two parts sand.

All work shall be done in a workmanlike manner by competent masons.

11.3. For each manhole or catch basin raised or lowered as directed by the Engineer, the Contractor shall receive the unit price bid.

The price bid shall include all labor, materials and incidentals necessary to complete the work. If any manhole or catch basin heads or covers are broken through carelessness on the part of the Contractor, they shall be replaced at his expense.

Item 12 — Cast-Iron Pipe

12.1. Under this item the Contractor shall furnish and place cast-iron pipe as directed for culverts, drains and other necessary uses, and of the sizes and weights ordered.

12.2. Pipe shall be of class A unless otherwise called for by the plans or ordered in writing by the Division Engineer, and may be second quality; but it shall be free from all defects impairing its strength or utility. The iron must be of good quality, uniform in thickness and of full strength. The pipe shall be coated with coal-pitch varnish mixed with linseed oil to form a firm, tough coating. Joints shall be formed by caulking into the hubs a gasket of jute or oakum and then filling with mortar composed of equal parts of Portland cement and clean, sharp sand. It shall be laid true to line and grade and shall have a full, firm, even bearing.

12.3. The number of tons of cast-iron pipe to be paid for under this item shall be the actual weight in place in the work as directed by the Engineer when of class A, or an equal weight when of heavier class; except that when a heavier weight is used under written order of the Division Engineer, such weight shall be paid for.

The price bid shall include the furnishing, delivering, handling, laying, cutting and all work and materials necessary to complete the work.

Item 13 — Relaying Old Pipe

13.1. Under this item the Contractor shall as directed carefully remove, preserve and relay old pipe found in existing culverts.

13.2. The old pipe when relaid shall be true to line and grade and have a full, firm, even bearing, and the work shall be in every way the same as if new pipe were being laid.

13.3. Any old pipe in good condition which is damaged in removing, due to the carelessness of the Contractor, shall be replaced with new pipe at the Contractor's expense.

Any old pipe which is, in the Engineer's judgment, unfit for relaying may be destroyed before removing.

13.4. The amount to be paid for under this item shall be the number of linear feet incorporated in the work. New pipe furnished to replace old pipe which is destroyed through the carelessness of the Contractor shall be paid for as if the old pipe had been preserved and relaid.

The price bid shall include all labor, materials and incidentals necessary to complete the work, except that the excavation necessary will be paid for under the item "EXCAVATION."

Item 14 — Stone Filling

14.1. Under this item the Contractor shall furnish and place acceptable stone of either quarry, field or cobble stone for filling crib work, and similar work as required.

14.2. Stone filling shall be of acceptable quarry, field or cobble stone. The larger stones shall be properly embedded at the bottom of the fill; all stones shall be so placed as to make a fill of maximum stability.

14.3. The quantity to be paid for under this item shall be the number of cubic yards measured in its final position and incorporated in the work as directed by the Engineer. The price stipulated shall include the cost of obtaining the stone, placing, and all materials and expenses incidental thereto.

Item 15 — Piles

15.1. Under this item the Contractor shall furnish and drive piles of acceptable material and lengths for foundations, revetment and elsewhere as required.

15.2. Piles shall be furnished to fit the localities. The Contractor shall, when required, drive preliminary test piles, each of which will be paid for at the contract price therefor. After the test piles are driven a statement will be furnished the Contractor by the Engineer, showing for the information of the Contractor the probable number of piles of the different kinds required, grouped between certain lengths in feet.

15.3. Piles shall be driven by hammer or combination of hammer and water jet methods, and the driving shall be satisfactory to the Engineer in every case. In driving piles the heads shall be protected from injury by a cap or shall be banded if required. The fall of the hammer shall not exceed 20 feet, and shall be regulated so as not to injure or shatter the pile. Driving shall continue until the penetration and bearing values are satisfactory to the Engineer.

15.4. The tops of all piles shall be sawed level and true to the elevation fixed by the Engineer.

15.5. Broken, split or misplaced piles shall be drawn and properly replaced. Piles driven below the grade fixed by the Engineer shall be drawn and replaced by new, and if necessary, longer, piles. No payment will be made for driving or withdrawing piles so injured or misplaced.

15.6. The number of linear feet paid for under this item shall be the total length of piles driven in accordance with plans or orders of the Engineer.

The price bid shall include the furnishing and delivering upon the work, the peeling, banding, tenoning, framing, driving, painting and all other labor and incidentals necessary to complete the work.

Item 16 — Timber and Lumber

16.1. Under this item the Contractor shall furnish timber and lumber of various sizes as may be ordered for sills or platforms beneath the road, for culverts, bridges, reinforcing existing structures and for other similar purposes as ordered by the Engineer.

16.2. Timber and lumber shall be of short leaf yellow pine or spruce or other acceptable kind, sound, square-edged, free from shakes, loose knots or decay, and shall be planed, and tongued-and-grooved if required.

16.3. No payments will be made under this item for timber or lumber for forms, moulds, or centers, for sheeting or bracing, scaffolds, fences, guard rails or any part of the contractor's temporary bridges, roads, or plant; but payment for timber and lumber used in the above cases shall be included under the appropriate items covering the same.

16.4. The quantity of timber and lumber to be paid for shall be the number of thousand feet, board measure, actually placed in accordance with orders of the Engineer. If any round timber is used it shall be estimated as square timber of the largest size, omitting fractions of an inch, which can be inscribed in the small end of the log.

No second hand timber shall be used except with the approval of the Engineer. The price bid shall include all bolts, spikes and other fastenings and all other material expenses incidental to furnishing, framing and placing the timber and lumber satisfactorily.

Item 17 — Rip-Rap

17.1. Under this item the Contractor shall furnish and place rip-rap for slope protection where shown upon the plans or ordered by the Engineer.

17.2. Rip-rap shall consist of field stone or rough, unhewn quarry stones as nearly cubical in form as is practicable, placed upon a slope not steeper than the angle of repose, and so laid that the weight of the large stones is carried by the soil and not by the stones adjacent. Fifty per centum of the mass shall be large stones of two cubic feet or more. The largest stones shall be placed first, roughly arranged and in close contact; the stones shall rest upon a 6-inch bed of stone chips or gravel or other acceptable porous material, where ordered by the Engineer. The spaces between the larger stones shall be filled with spalls of suitable size.

17.3. The quantity of rip-rap to be paid for under this item shall be the number of cubic yards placed in accordance with the plans or as directed by the Engineer. When a porous bed is placed in

accordance with the directions of the Engineer, the quantity of the same shall be included in the quantity of rip-rap and paid for as such.

The price bid shall include all labor, materials and incidental expenses necessary to satisfactorily complete the work.

CONCRETE MASONRY

Item 18 — First-Class Concrete
Item 19 — Second-Class Concrete
Item 20 — Third-Class Concrete

18.1. Under Items 18, 19 and 20 the Contractor shall place concrete of the class indicated on the plans or ordered by the Engineer, for culverts, abutments, wing walls and in other structures as directed by the Engineer.

This item shall not include concrete used in curbs, catch-basins, edging, sign posts, guard railing, resetting old curb, concrete pavement foundations or "Concrete Pavements" or in other structures for which there is a contract item, unless it is specifically stated under that item that such shall be the case. All concrete placed in the work, whether included under Items 18, 19, or 20 or under other items, shall conform to the requirements for concrete of the class specified.

18.2. Concrete shall consist of approved Portland cement, a fine aggregate of sand, and a coarse aggregate of broken stone or gravel, mixed in the proportions specified for the various classes given below. Samples of all these ingredients shall be submitted to and approved by the Bureau of Tests, and shall be acceptable to the Engineer before being used in the work.

18.3. Concrete will be classified as follows:

First-class concrete shall be made of one part Portland cement, two parts of No. 1 or No. 2 sand (see page 374) and four parts of coarse aggregate.

Second-class concrete shall be made of one part Portland cement, two and one-half parts of No. 2 or No. 3 sand, and five parts of coarse aggregate.

Third-class concrete shall be made of one part of Portland cement, three parts of No. 3 sand, and six parts of coarse aggregate.

Cement, fine and coarse aggregate shall be proportioned by loose volumes. For this purpose one bag of cement shall be considered as $\frac{95}{100}$ of a cubic foot. The fine and coarse aggregate shall be measured separately.

PORTLAND CEMENT

18.4. All the cement used in the work shall conform to the requirements given under "MATERIALS OF CONSTRUCTION," pages 372–374; it shall be subject to rigid inspection, shall be sampled by the Engineer at once on delivery, and shall conform to the prescribed tests made at the testing laboratories of the Bureau of Tests. All cement which is rejected because of failure to stand the required tests shall be immediately removed at the expense of the contractor.

18.5. Cement barrels shall contain 376 pounds of Portland cement. Each bag of Portland cement shall contain 94 pounds net.

18.6. Provision shall be made by the Contractor for storing cement in a dry place.

FINE AGGREGATE

18.7. Fine aggregate shall conform in all respects to the requirements given under "MATERIALS OF CONSTRUCTION," page 374. Sand which contains foreign matter shall be satisfactorily washed before using. Screenings shall not be used except when they have been submitted by the Division Engineer to the Bureau of Tests, have been accepted by the Bureau of Tests, and their use has been approved by the First Deputy Commissioner in writing, and then only under the restrictions laid down under "MATERIALS OF CONSTRUCTION," page 375.

COARSE AGGREGATE

18.8. Coarse aggregate shall conform in all respects to the requirements given under "MATERIALS OF CONSTRUCTION," page 375. Materials which contain foreign matter shall be satisfactorily washed before using.

MIXING, DEPOSITING AND FINISHING CONCRETE

18.9. Approved batch mixers shall be used in all cases where required by the Engineer. No continuous mixer shall be used. Mixing shall continue through at least twelve revolutions of the mixer, and until every face of every particle of stone of gravel is completely coated with mortar. In all machine mixing the batches of concrete shall be proportioned to the size of the mixer to produce the best results.

18.10. If hand mixing is permitted the following method shall be used:

The sand and cement shall be thoroughly mixed dry and made into a thin mortar. After the mortar has been brought to the proper consistency, the broken stone or gravel, having been just previously drenched with water, shall be added, and the whole thoroughly mixed to the satisfaction of the Engineer. The mixing shall be done upon water-tight platforms, in a satisfactory manner; after the materials are wet, the work shall proceed rapidly until the concrete is in place, and is so thoroughly manipulated that water flushes to the surface and all the interstices between the stones are entirely filled with mortar.

18.11. All mortar and concrete shall be used while fresh and before the initial set has begun. Any mortar or concrete in which the initial set has begun shall be removed from the mixing boards or receptacle and not used in the work. No retempering of mortar or concrete shall be allowed.

18.12. The quantity of water to be used in making concrete shall be determined by the Engineer, but in general a wet mixture shall be used as tending to produce a uniform, dense and impervious concrete.

18.13. When required by the Engineer, concrete shall be deposited in layers averaging not more than six inches in thickness before compacting. In joining new concrete to old, or to concrete that has already set, the work already in place shall have its surface cut over thoroughly with picks to remove all laitance, loose and foreign material; this surface shall then be washed and be scrubbed with wire brooms before the new concrete is placed. In order to bond the successive courses, horizontal keys shall be formed at the top of the upper layer of each day's work and at such other levels as work is interrupted until the concrete has taken its initial set. Rough stone may, at the discretion of the Engineer, be embedded instead of using the keys.

Whenever concreting is suspended on any section for more than one hour, all edges which will be exposed in the finished work shall be brought to a level.

In any given layer the separate batches shall follow each other so closely that each one shall be placed and compacted before the preceding one has set, so that there will be no line of separation between the batches.

After the concrete has begun to set, it shall not be walked upon in less than twelve hours.

The operation of compacting the concrete shall be conducted so as to form a compact, dense, impervious artificial stone which shall show a smooth face on exposed surfaces. The weight of rammers, if used, shall be satisfactory to the Engineer. If any monolith, the concrete of which is found porous, has been plastered or is otherwise defective, it shall be removed and replaced in whole or in part, as directed by the Engineer, entirely at the Contractor's expense.

18.14. The Contractor shall construct suitable forms, the cost of which shall be included in the contract price per cubic yard for the concrete, the interior shape and dimensions of which shall be such that the finished concrete shall be of the form and dimensions shown on the plans. Lagging for faces shall not be less than two (2) inches in thickness before being dressed, except where used for curved or special surfaces. Especial attention must be paid to bracing, and where the forms appear to be insufficiently braced, or unsatisfactorily built, either before or during concreting, the Engineer shall order work to be stopped until the defects have been corrected to his satisfaction. If desired, small rods to hold the forms may be embedded in the concrete, but in all such cases provision must be made by sleeve nuts or other satisfactory methods for the removal of the two inches nearest the surface. All holes thus left shall be immediately and completely filled with cement mortar and the surface left smooth and even. All forms shall be set and maintained true to the lines designated until the concrete is sufficiently hardened. All forms shall be satisfactory to the Engineer and shall remain in place as long as he deems necessary. The interior surfaces of the forms which come in contact with the surfaces of the concrete which will be exposed in the finished work shall be of lumber dressed on both faces and both edges and having water-tight joints, and shall be so constructed as to leave all such exposed surfaces of the concrete with a smooth even

finish. Forms reused shall be maintained at all times in good condition as to accuracy of shape, strength, rigidity, watertightness and smoothness of surface. Forms unsatisfactory in any respect shall not be used, and if condemned shall be removed immediately from the work.

18.15. Boulders and fragments of rock may be bedded in a large mass of third-class concrete. Each stone before being bedded or placed shall be thoroughly washed and scrubbed, if necessary, to free it from all dirt. Stones bedded in concrete shall be at least three inches apart at all points, and no stones shall be placed within three inches of any face of the concrete. Stones shall be laid on their largest bed and worked down into the concrete by bars so as to exclude the air from any pockets in the lower surface of the stone.

18.16. The Contractor shall construct weep holes in all retaining walls at such points as are indicated on the plans or designated by the Engineer. Selected stones shall be placed by hand at the inner end of the holes to assist drainage in escaping and to prevent the overflow of earth. Payment for all labor and materials required to construct and protect these weep holes will be included in the contract price for concrete.

18.17. Whenever directed by the Engineer, newly laid masonry shall be protected to prevent freezing, and the protection shall be in all respects satisfactory to him.

The Contractor shall be responsible for all damage to concrete by freezing, and any concrete so damaged shall be cut out and replaced at the Contractor's expense as directed by and to the satisfaction of the Engineer.

When the temperature falls below 35 degrees Fahrenheit the fine aggregate, water and stone shall be heated, and the newly laid concrete shall be covered with canvas or otherwise protected from freezing. No concrete foundation for pavement or concrete pavement shall be laid when the temperature falls below 35 degrees Fahrenheit.

18.18. All damage to or disfigurement of concrete of any kind occurring prior to the final acceptance of the work shall be remedied by the Contractor at his own expense and to the satisfaction of the Engineer.

18.19. No piece of stone shall be left within one inch of any face, a broad-tined fork or other implement, if approved, being thrust between the form and the concrete to pry the fragments of stone back from the face.

The top surface of concrete shall be formed immediately after the underlying course is completed and before this course takes its initial set. The top surface shall be formed by cutting off the excess with a template and shall then be rubbed smooth and hard with a wooden float by skilled men. As soon as the concrete has sufficiently set and the Engineer shall so direct, the forms shall be removed and all exposed faces immediately finished by being rubbed smooth with a mortar block and water. No plastering of any surface will be allowed, the required finish being obtained by rubbing down the irregularities of the face. All exposed surfaces shall be smooth,

dense, without pits, irregularities, blow holes or bubbles. The surface of all finished and unfinished work shall be kept wet for a period of six days unless otherwise directed by the Engineer.

All edges, joints of sections and angles which will be exposed in the finished structure shall be rounded. A radius of one inch shall be used unless otherwise designated on the plans or directed by the Engineer.

18.20. Concrete shall not be laid in water nor exposed to the action of the water before setting, except by written permission of the Engineer, and then in such manner as he may specially direct.

18.21. Where concrete is to rest on any excavated surface other than rock, special care shall be taken not to disturb the bottom of the excavation, and the final removal of material to grade shall not be made until just before the concrete is laid, except in concrete foundations for pavement.

The excavation lines and bases of structures shown on the plans shall be considered as only approximate; and they may be ordered in writing by the Engineer, to be placed at any elevation or of any dimensions that will give a satisfactory foundation. Any additional concrete that may be required by the Engineer below or beyond the lines shown on the plans will be paid for at the contract price.

No structure shall be commenced without the Engineer's approval.

All rock or hardpan foundation surfaces shall be freed from loose pieces, cut to firm surfaces and cleaned to the satisfaction of the Engineer, before laying concrete. All seams shall be cleaned out and filled with concrete or mortar; and payment for such cleaning out and filling shall be made at the contract price for the class of concrete used.

18.22. The quantity to be paid for under Items 18, 19 and 20 shall be the number of cubic yards of the various classes measured in place in the finished structures placed in accordance with the plans or as ordered by the Engineer. No payment will be made for any concrete outside of these limits, nor for any concrete whose placing is rendered necessary owing to lack of proper care.

The price bid for Items 18, 19 and 20, respectively, shall include all materials, forms, labor and other incidental expenses necessary to satisfactorily complete the work as specified in the foregoing paragraphs for first-class concrete, second-class concrete and third-class concrete respectively.

Item 21 — Stone Masonry

21.1. Under this item the Contractor shall furnish and build all stone masonry in structures or elsewhere, as shown upon the plans or ordered by the Engineer.

21.2. Stone masonry shall be built of clean stone, free from structural defects, laid in full cement mortar beds. Selected stone, roughly squared and pitched to line, shall be used at all angles and ends of walls.

21.3. The stone shall be laid on its natural bed to form substantial masonry, presenting a neat and finished appearance. Spalls and pinners shall not be allowed to show on the face of the wall, and

shall be used only where necessary. The length of stretchers shall not exceed three times their rise; the width of stretchers shall in no case be less than their rise. At least one-fourth of the stone in the face shall be headers, and these shall be evenly distributed; the length of headers shall not be less than the thickness of the wall, where the wall is four feet or less in thickness; where the wall is more than four feet in thickness, the length of the headers shall not be less than two feet and eight inches, and not more than two-thirds of the thickness of the wall; the width of the headers shall not be less than their rise. All stones shall be laid to break joints six inches or more and to thoroughly bond the work. No joint of the face shall be over one inch in width. Backing shall consist of good-sized, well-shaped stone so laid as to break joints. All spaces between the stone shall be filled with spalls set in mortar. The rear faces shall present approximately plain surfaces.

21.4. End walls of culverts and retaining walls shall be capped with concrete or with stone, roughly squared, extending across the entire width of the wall, and on steps of wing walls the coping shall extend under the step next above it at least eight inches.

21.5. On all exposed faces, the joints shall be raked out and cleaned to a depth of two inches and then pointed with Portland cement mortar mixed in a proportion of one to one.

21.6. The quantity of stone masonry to be paid for under this item shall be the number of cubic yards measured in the completed work, and the limits shall not exceed those shown upon the plans or fixed by the Engineer.

The price bid shall include all labor, materials and incidental expenses necessary to satisfactorily complete the work.

Item 22 — Stone Curbing and Headers

22.1. Under this item the Contractor shall furnish and place stone curbing and headers where shown on the plans or ordered by the Engineer.

22.2. Stone curbing and headers shall be of approved bluestone, sandstone or granite, sound, uniform, free from seams or other imperfections, and shall be nowhere less than 5 inches thick, 15 inches deep, and 3 feet long.

The upper face shall be evenly cut and the front face shall be dressed for the full depth to an even surface with no projections or depressions exceeding one-quarter inch. The bottom shall be roughed off parallel to the top so that there will be no projections exceeding 2 inches beyond the required depth.

The ends shall be squared and dressed to form joints not exceeding one-eighth inch for a depth of at least 2 inches from top and front face. The backs shall be rough dressed for full depth and dressed the same as the face for a depth of 2 inches from the top. The joints of circular curbing shall be cut on radial lines.

22.3. The curb or header shall be set in third-class concrete, as shown on the plans. It shall be true to line and grade and settled so as to have a firm and uniform bearing.

22.4. If required by the plans, porous drain-tile shall be placed under stone curbing and firmly embedded and covered with cinders, gravel or broken stone.

22.5. After the curb or header has been set the trenches shall be filled with earth and thoroughly tamped.

22.6. The quantity to be paid for under this item shall be the number of linear feet of curbing or headers set in accordance with plans and directions of the Engineer.

The price bid for this item shall include the furnishing and setting of the curb or header, all concrete, tile, broken stone or gravel, and all labor, materials and incidental expenses necessary to complete the work.

Item 23 — Resetting Old Curbing

23.1. Under this item the Contractor shall remove and reset old curbing, as shown upon the plans or ordered by the Engineer.

23.2. Care shall be taken in removing old curbing so that there shall be no unnecessary breakage, and any curbing damaged in removing, hauling, or storing, due to the carelessness of the Contractor, shall be replaced with new curbing at his own expense.

23.3. All joints and tops shall be redressed, if directed by the Engineer, to obtain a smooth top surface and to obtain joints of the same class as specified for new curbing.

23.4. The quantity to be paid for under this item shall be the number of linear feet removed, stored, hauled, and reset in accordance with the plans and as directed by the Engineer.

The price bid shall include all concrete, tile, removing, redressing, hauling, storing, resetting, and all materials, labor and incidental expenses necessary to complete the work.

Item 24 — Concrete Curbing

24.1. Under this item the Contractor shall place concrete curbing, of the type shown on the plans, where shown on the plans or ordered by the Engineer.

24.2. All curbing shall be constructed of first-class concrete. The concrete shall be of such consistency, and be so spaded and worked, that a smooth mortar face will be produced. The coarse aggregate for concrete curbing shall be approved No. 2 stone or gravel.

24.3. Curbing shall be moulded in place in sections 6 feet long and provision made at each joint for expansion of one-sixteenth inch.

24.4. All forms shall be set true to line and grade and held rigidly in position. They shall be either of metal or of acceptable planed and matched lumber, and of such construction that a smooth surface will be provided.

The forms shall be left in place until the concrete has set sufficiently so that they can in the opinion of the Engineer be removed without injury to the curbing. The curbing shall immediately upon the removal of the forms be rubbed down to a smooth and uniform surface, but no plastering will be allowed. For this work a competent and skillful finisher shall be employed.

24.5. The Contractor shall protect the curbing and keep it in first-class condition until the completion of the contract. Any curbing which is damaged at any time previous to the final acceptance of the work shall be removed and replaced with satisfactory curbing at the Contractor's expense. (Also see section 18.1.)

24.6. The quantity to be paid for under this item shall be the number of linear feet placed in accordance with the plans or directions of the Engineer.

The price bid for concrete curbing shall include the furnishing and placing of all concrete, tile, porous filling, forms, and all other materials, labor and incidental expenses necessary to complete the work.

Item 25 — Concrete Edging

25.1. Under this item the Contractor shall furnish and mould in place concrete edging of the type shown on the plans and where designated on the plans or ordered by the Engineer.

25.2. The concrete edging shall be composed of second-class concrete. The top shall be troweled to an even surface and the material shall be rammed and spaded so that a dense concrete and a smooth surface will result. (Also see section 18.1.)

25.3. The forms shall be set and held true to line and grade, and shall not be removed until the concrete has set sufficiently, in the judgment of the Engineer, so that no harm will result therefrom. The edging shall be protected from injury until the completion of the contract.

After the removal of the forms, the trenches shall be back-filled with earth and thoroughly tamped.

25.4. The quantity to be paid for under this item shall be the number of linear feet of concrete edging completed as shown on the plans or ordered by the Engineer.

The price bid shall include the furnishing and placing of concrete and forms, and all other materials, labor and incidentals necessary to complete the work.

Item 26 — Cobble Gutters

26.1. Under this item the Contractor shall furnish and place cobble gutters where shown on the plans or ordered by the Engineer.

26.2. Cobble gutters shall consist of rounded "hardheads," quarry or field stone, and shall be laid on edge. If hardheads are used they shall be 4 inches to 8 inches in diameter. The largest stones shall be selected and set along the edges of the gutter. All stones except where embedded in mortar shall be set in sand, and shall be laid to line and grade with close joints by skilled workmen using regular paving tools. The whole shall then be thoroughly rammed in place and brought to a uniform surface. All joints shall be swept full of sand. On grades exceeding 6 per centum, and elsewhere if called for by the plans or ordered by the Engineer, cobble gutters shall be laid in Portland cement mortar, mixed one to three, as shown upon the plans.

26.3. The quantity of cobble gutter to be paid for under this item will be the number of square yards of exposed surface laid in accordance with the plans and as directed by the Engineer.

The price bid shall include the furnishing and placing of all stones, sand, mortar, and all other materials, labor and incidental expenses necessary to complete the work.

Item 27 — Concrete Gutters

27.1. Under this item the Contractor shall furnish and place concrete gutters where shown upon the plans or ordered by the Engineer.

27.2. Concrete gutters shall be of first-class concrete and shall conform to all requirements therefor as elsewhere specified. They shall be of the shape and length shown upon the plans, and shall be placed true to line and grade as directed. (See section 18.1.)

27.3. The quantity for which the Contractor will be paid shall be the number of square yards of concrete gutters placed in accordance with the plans and ordered by the Engineer.

The price bid shall include the furnishing and placing of all concrete, the preparation of foundation, together with all other labor and incidental expenses necessary to satisfactorily complete the work.

Item 28 — Brick Gutters

28.1. Under this item the Contractor shall furnish and place brick gutters where shown upon the plans or ordered by the Engineer.

28.2. Brick gutters shall be constructed of approved brick, shall conform to the dimensions shown upon the plans, and shall be laid true to lines and grades upon a suitable bed of sand.

28. 3. Where brick gutters are to be laid next to a curbing in connection with a pavement having a concrete foundation, they shall be constructed in full conformity to the specifications for brick pavement, and shall be paid for as such.

28.4. The quantity for which the Contractor will be paid shall be the number of square yards of brick gutters placed in accordance with the plans and ordered by the Engineer.

The price bid shall include the furnishing and placing of all materials and the preparation of bed, together with all other labor and incidental expenses necessary to satisfactorily complete the work.

Item 29 — Metal Reinforcement

29.1. Under this item the Contractor shall furnish and place metal bar and metal mesh reinforcing material where shown upon the plans or directed by the Engineer.

29.2. All metal reinforcement shall, when embedded, be free from mill scale, grease, injurious rust, dirt or other foreign substance.

29.3. All metal reinforcement shall be securely held in place so that it will be in the prescribed position after the concrete has been thoroughly compacted.

29.4. Unless otherwise designated upon the plans, all bar reinforcement shall be of open hearth steel, and shall consist of approved "deformed" bars or rods which shall have an elastic limit of not less than 30,000 nor more than 45,000 pounds per square inch, and an elongation of not less than 20 per centum in a length of 8 inches.

Deformed bars shall not contain more than $\frac{5}{100}$ of one per centum of sulphur nor more than $\frac{4}{100}$ of one per centum of phosphorus. In small culverts and other structures of minor importance standard commercial deformed bars acceptable to the Engineer may be used.

All deformed bars shall be uniform in quality, and shall endure bending 180 degrees, when cold, around a circle whose diameter is equal to the diameter or thickness of the test piece, without fracture on the outside of the bent portion.

Bars shall overlap each other by 30 diameters.

29.5. Unless otherwise designated upon the plans, all metal mesh reinforcement shall be of an approved kind and quality, and of the cross-section shown upon the plans and acceptable to the Engineer, and equal in all respects to the best standard commercial products. Sheets of metal mesh shall overlap each other as directed by the Engineer or as shown upon the plans.

29.6. The quantity of metal reinforcement for which the Contractor will be paid shall be the number of pounds incorporated in the work in accordance with the plans or directions of the Engineer.

The bid price shall include all labor, materials, and other expenses necessary to satisfactorily complete the work.

Metal reinforcement used in rails and posts shall not be included in this item, but shall be considered as being included in the price bid for appropriate items.

Item 30 — Miscellaneous Iron and Steel

30.1. Under this item the Contractor shall furnish and place all cast iron, wrought iron and steel not especially included in other items as shown on the plans and for miscellaneous structures as ordered by the Engineer. This item shall include beams, channels, and other structural shapes, as well as miscellaneous iron castings, wrought iron, etc.

30.2. All structural steel, bolts, etc., shown on the plans may be of stock steel. Stock steel shall be subjected only to surface inspection and cold bending tests. Test pieces cut from finished materials shall endure bending cold, without signs of cracking, 180 degrees around a circle whose diameter is equal to the thickness of the test piece.

Iron castings shall be made of the best tough gray iron of uniform quality and shall be free from defects and uneven shrinkage. No mill cinder iron, white or burnt iron or scrap of any kind shall be used. They shall be clean, out of wind, and true to dimensions. Castings having blow holes plugged or filled with putty or crust shall not be used.

Wrought iron shall be tough, fibrous and uniform in quality and shall be manufactured by approved methods. Steel scrap shall

not be used in its manufacture. Finished material shall be clean, smooth, true to shape and free from defects.

All iron and steel except cast iron shall be given a shop coat of red lead and oil, and after being placed shall be given two coats of approved paint.

30.3. The quantity of iron, wrought iron and steel to be paid for under this item shall be the number of pounds furnished and placed in accordance with the plans or instructions of the Engineer. The price bid shall include the furnishing, placing, painting and all other labor, materials and incidental expenses necessary to satisfactorily complete the work.

Item 31 — Wooden Guard Railing

31.1. Under this item the Contractor shall furnish and erect wooden guard railing of the type indicated, where shown on the plans or ordered by the Engineer.

31.2. The posts shall be of seasoned white oak, cedar, locust, tamarack, white pine, or chestnut. They shall be at least 6 inches square, or if round they shall be 6 inches in diameter at the smaller end after the bark is removed, and 7 feet long. Round posts shall be shaved to even surfaces free from bark or skin. The lower part of the posts to a point 3 feet from the top shall be dipped while dry in suitable bituminous material heated to a temperature of 300 degrees Fahrenheit, or shall be charred as directed. The posts if dipped shall be thoroughly dry before being set in the ground.

31.3. Rails shall be of seasoned, planed spruce or other satisfactory wood, and be properly secured to the posts, all in a workmanlike manner.

31.4. The joints of the rails and posts shall be given one coat of white lead and linseed oil before being put together; the beveled tops of posts shall receive two heavy coats of the same. The entire surface exposed above the ground shall be painted with three coats of white lead and linseed oil.

31.5. The white lead and the linseed oil shall be delivered separately on the road in original containers; before being mixed and used a pint sample of each, covering each lot, shall be forwarded to the Bureau of Tests, and neither ingredient shall be used until accepted by the Commission. The mixing of the ingredients shall be as directed by the Engineer. This specification shall apply to all paint used under this contract.

31.6. The quantity of wooden guard railing to be paid for under this item shall be the number of linear feet completed in place.

The price bid shall include the furnishing and erecting of all posts and rail, the excavation, painting, dipping, hardware and all expenses and incidentals necessary to complete the work.

Item 32 — Special Guard Railing

32.1. Under this item the Contractor shall furnish and erect, true to line and grade, guard railing of the special design shown upon the plans, at the places indicated by the plans or ordered by the Engineer.

32.2. Except as otherwise provided by the plans, each class of work necessitated under this item shall be governed by the clauses of other items which are specially applicable thereto.

32.3. The quantity of guard railing to be paid for under this item shall be the number of linear feet placed in accordance with the plans and ordered by the Engineer.

The price bid shall include all excavation, concrete, metal reinforcement, hardware, backfilling and all other materials, labor and incidental expenses necessary to satisfactorily complete the work.

Item 33 — Pipe Railing

33.1. Under this item the Contractor shall furnish and erect pipe railing of the type indicated where shown upon the plans or ordered by the Engineer.

33.2. Pipe railing shall consist of wrought iron pipe, rails, posts and pipe rail fittings of the sizes shown on the plans. All threaded joints shall be coated with lead and oil before being assembled. All parts shall be painted, after being put in place, with two coats of white lead and linseed oil.

33.3. The quantity of pipe railing to be paid for under this item shall be the number of linear feet placed in accordance with the plans and ordered by the Engineer.

The price bid shall include the furnishing and erecting of all materials, the painting and all expenses and incidentals necessary to complete the work.

Item 34 — Guide Signs

34.1. Under this item the Contractor shall furnish and erect guide signs of the type indicated where shown upon the plans or ordered by the Engineer.

34.2. Permanent guide signs shall be for the purpose of furnishing permanent directions to traffic after the completion of the contract. Permanent guide signs shall be constructed of kiln dried white pine and of the dimensions shown on the plans. They shall first be given four coats of white lead mixed with linseed oil. After the last coat has become thoroughly dried the letters shall be painted with black enamel paint, and when this is thoroughly dried they shall be given one coat of the finest white shellac.

34.3. Temporary guide signs shall be for the purpose of guiding traffic along a detour during construction. Temporary guide signs shall be constructed of kiln dried white pine and of the dimensions shown on the plans. They shall first be given three coats of white lead mixed with linseed oil. After the last coat has become thoroughly dried the letters shall be painted with black enamel paint.

34.4. The number of guide signs to be paid for under this item shall be the number of signs placed in accordance with the plans and ordered by the Engineer. All signs become the property of the State upon payment for this item.

The price bid shall include the furnishing of all labor and materials necessary to satisfactorily erect permanent guide signs on sign posts and temporary guide signs including sign posts, each guide sign complete in place.

Item 35 — Highway Number Signs

35.1. Under this item the Contractor shall paint on the concrete sign posts highway number signs of the type indicated where shown upon the plans or ordered by the Engineer.

35.2. Highway number signs shall be painted on all concrete sign posts with letters which shall first be formed of two coats of flat black mixed in oil and afterward retraced with black enamel.

35.3. The number of highway number signs to be paid for under this item shall be the number placed in accordance with the plans and ordered by the Engineer.

The price bid shall include the furnishing of all labor and materials to satisfactorily complete the work.

Item 36 — Danger Signs

36.1. Under this item the Contractor shall furnish and erect danger signs where shown upon the plans or ordered by the Engineer. These shall be of the type called for by the plans.

36.2. Danger signs shall be constructed of a material and painted similar to that specified for guide signs and shall be of the dimensions and lettered as shown on the standard plans. These signs shall be placed on the standard concrete sign posts and set at an angle of forty-five degrees to the center line. When the standard sign is used the arrow shall point in the direction of the danger.

36.3. The number of completed danger signs for which the Contractor will receive payment will be the number placed in accordance with the plans and ordered by the Engineer.

The price bid shall include the furnishing of all labor and materials necessary to complete each danger sign in a satisfactory manner.

Item 37 — Concrete Sign Posts

37.1. Under this item the Contractor shall furnish and erect concrete sign posts of the type indicated, where shown upon the plans or ordered by the Engineer.

37.2. Concrete sign posts shall be made of first-class concrete and of the dimensions and materials shown on the standard plans. To these posts shall be securely fastened guide boards and signs.

37.3. The number of completed concrete sign posts to be paid for under this item shall be the number erected in accordance with the plans and ordered by the Engineer.

The price bid shall include all concrete, reinforcement, forms, excavation and backfill, and the furnishing of all other labor and materials necessary to complete each concrete sign post in a satisfactory manner.

LOOSE STONE

Item 38 — Screened Gravel — Loose Measure
Item 39 — Broken Stone — Loose Measure

38.1. Under these items the Contractor shall furnish and place upon the road, as directed by the Engineer, broken stone and gravel of the sizes designated on the Itemized Proposal. This stone and gravel will be used for general repair work and for miscellaneous work.

38.2. The stone or gravel delivered shall be of approved quality and shall conform to the general requirements for broken stone and gravel, and they shall be of the sizes ordered.

38.3. The quantity to be paid for under Items 38 and 39 respectively shall be the quantity of broken stone or gravel furnished and delivered on the work at the places and in the condition specified by the Engineer. When the material is produced by the contractor on the work, it shall be measured in cubic yards; it shall be measured in tons of 2,000 lbs. when the material is imported and the weight is obtainable from reliable sources such as certified quarry or railroad figures.

The price bid shall include furnishing and delivering the stone or gravel as directed by the Engineer and all labor, appliances and expenses incidental thereto; also the spreading, rolling or incorporating of the stone or gravel in the work, when required by the Engineer.

FOUNDATION COURSE

Item 40 — Foundation Course — "Run of Bank" Gravel
Item 41 — Foundation Course — Field of Quarry Stone

40.1. Under these items the Contractor shall furnish and place a foundation course of stone or gravel of the depth and in the places called for by the plans, or as ordered by the Engineer in accordance with section 2.5, "Preparation of Subgrade" of item "Excavation."

40.2. No stone or gravel shall be placed on the road until the culverts are completed and proper drainage provided.

40.3. When field or quarry stone is used for constructing the foundation course it shall be of a hard, sound and durable quality, acceptable to the Engineer; the stones shall be placed by hand so as to bring them in as close contact as possible. When quarry stones are used they shall be placed on edge. The depth of the stone shall in no case be greater than the depth specified for the course, the width shall not be greater than the depth, nor more than six inches; and the length shall not be greater than one and one-half times the depth, nor more than 12 inches. The distribution of the stone shall be of a uniformity satisfactory to the Engineer. The long dimension shall always be placed crosswise the road. After laying, this course shall be thoroughly rolled with an approved roller weighing not less than ten tons, and shall then be filled with stone or gravel as directed and again rolled until the stones are bound together and

thoroughly compacted; but no gravel shall be used for filling except under written permission of the Engineer. All holes or depresssions found in rolling shall be filled with material of the same quality and the surface shall be re-rolled until it conforms to the lines and grades shown on the plans. When field stone is used approved tailings may be used for filling. In all cases a sufficient amount of fine material shall be used to fill all voids. In limited areas where the use of a roller is impracticable heavy tampers may be used to consolidate the material.

40.4. Wherever gravel is used for the foundation course it shall conform in all particulars to the gravel specified in section 2 of Bottom Course "Run of Bank" Gravel.

40.5. The quantity to be paid for under this item shall be the number of cubic yards of compacted material in place. The amount to be estimated shall be computed by multiplying the finished cross-section of the foundation course as shown upon the plans or ordered by the Engineer, by the length of the foundation course measured along the axis of the pavement.

The price bid shall include the furnishing, placing, filling, rolling of the material and all labor and incidental expenses necessary to complete the work.

Item 42 — Foundation Course — Telford Base

42.1. Under this item the Contractor shall furnish and place a foundation course of field or quarry stone laid on edge, in accordance with the plans or as ordered by the Engineer.

42.2. No stone shall be placed on the road until the culverts are completed and proper drainage has been provided.

42.3. Field or quarry stone of approximate rectangular shape shall be used. The stone shall be not less than one and one-half inches thick, in depth equal to the depth of the course, and in length not more than one and one-half times the depth.

42.4. The pieces shall be placed on edge by hand in as close contact as possible with long dimension crosswise of the road. After being placed, all pieces projecting more than one inch above the established plane of the surface shall be broken off flush so as to obtain a true and uniform surface. This course shall then be rolled with an approved self-propelled roller weighing not less than ten tons, and shall then be filled with approved screenings and again rolled until the course is thoroughly compacted. Material other than screenings for filling this course shall not be used except under the written order of the Engineer.

42.5. The quantity to be paid for under this item shall be the number of cubic yards of compacted material in the completed course. The amount to be estimated shall be computed by multiplying the finished cross-section of the foundation course as shown upon the plans or ordered by the Engineer, by the length of the foundation course measured along the axis of the pavement. The price bid shall include the furnishing, placing, filling, rolling of the material and all labor and incidental expenses necessary to complete the work.

BOTTOM COURSE

Item 43 — "Run of Bank" Gravel

43.1. Under this item the Contractor shall furnish and place approved "Run of Bank" gravel either upon the properly prepared subgrade or upon the foundation course. The work shall be performed in full conformity to the specifications given under sections 44.2 to 44.9 inclusive, so far as same are not inconsistent with the use of such gravel.

43.2. All gravel shall be of hard, durable stone satisfactory to the Engineer. The particles shall be of such size as will pass through a $3\frac{1}{2}$-inch circular hole, and shall be well graded. Gravel shall be of such nature that the material passing a $\frac{1}{4}$-inch screen shall not be more than five per[1] centum in excess of the voids in the remaining material after its separation therefrom. Before using "Run of Bank" gravel in the work the same shall be tested to determine its suitability. Should at any time during the work and for any reason the gravel fail to maintain suitable proportions of the coarse and fine particles, the Contractor shall by the addition of selected material and satisfactory manipulation produce a material meeting the above requirements.

43.3. The depth of loose stone or gravel in all cases, whether in foundation, bottom or top courses, shall be gauged by the use of cubical blocks of suitable size. (See page 272.)

43.4. The spreading of any layer or course of broken stone, gravel or filler, whether in foundation, bottom or top courses, shall be done from suitable spreader wagons or from piles dumped along the road as directed by the Engineer.

No segregation of large or fine particles will be allowed, but the stone as spread shall be well graded with no pockets of fine material.

43.5. The quantity to be paid for under this item shall be the number of cubic yards of compacted material in place in the completed course. The amount to be estimated shall be computed by multiplying the finished cross-section of the bottom course as shown on the plans or ordered by the Engineer, by the length of the bottom course measured along the axis of the pavement.

The price bid shall include the furnishing, placing, rolling and filling the material, and all other labor, materials and incidental expenses necessary to satisfactorily complete the work.

Item 44 — Bottom Course — Screened Gravel
Item 45 — Bottom Course — Broken Stone

44.1. Under these items the Contractor shall furnish and place stone or gravel, conforming to the general requirements for same, either upon the properly prepared subgrade or upon the foundation course. This stone or gravel shall be of sizes specified below.

44.2. After the subgrade or foundation course shall have been properly prepared and proper drainage provided, a course of broken

[1] Not feasible, see page 69.

stone or gravel of graded No. 3 or No. 4 or a uniform mixture of same shall be spread evenly so that it will have after rolling the required thickness. If specifically allowed by the Engineer a limited amount of No. 2 stone may be used in the bottom course.

In cases where the finished thickness of the bottom course is to be more than 5 inches, the broken stone or gravel for it shall be spread, rolled and filled in two separate layers neither of which shall be of a greater depth than 6 inches measured loose.

44.3. The depth of loose sotne or gravel in all cases, whether in foundation, bottom or top courses, shall be gauged by the use of cubical blocks of suitable size. (See page 272.)

44.4. The spreading of any layer or course of broken stone, gravel or filler, whether in foundation, bottom or top courses, shall be done from suitable spreader wagons or from piles dumped along the road as directed by the Engineer.

No segregation of large or fine particles will be allowed, but the stone spread shall be well graded with no pockets of fine material.

44.5. After the bottom course of stone or gravel has been laid loose it shall be thoroughly rolled with an approved roller weighing not less than ten tons.

This rolling must begin at the sides and continue toward the center and shall continue until there is no disturbance of the stone ahead of the roller. After the stone is thoroughly compacted No 1. stone or gravel, and screenings or sand, or a mixture of these, shall be uniformly spread upon the surface and swept in with rattan or steel brooms and rolled dry. After the completion of the rolling no teaming other than that necessary for bringing material for the next course shall be allowed over the rolled material. It is the intention to bind this course with the small stone, but not to use so much that a good bond will not be secured between the bottom and top courses.

44.6. When two courses of bottom stone are laid each course shall be treated by rolling and adding fine material as described above.

44.7. If the subgrade material shall become churned up into or mixed with the bottom or sub-bottom courses through the Contractor's hauling over it or working on it when the subgrade is in a wet condition, the Contractor shall at his own expense remove such mixture of subgrade material and broken stone and replace it with clean broken stone of the proper size, and shall roll or otherwise compact the material so as to produce a uniform, firm and even bottom course.

If the above condition occurs through no fault of the Contractor, the Contractor shall be paid both for excavating and replacing under the items "Excavation" and "Bottom Course" respectively.

44.8. All filler for top and bottom courses shall be delivered and piled alongside the road before the course in which it is to be used is placed.

44.9. The quantity to be paid for under these items respectively shall be the number of cubic yards of compacted material in place in the completed course. The amount to be estimated shall be computed by multiplying the finished cross-section of bottom course as shown upon the plans or ordered by the Engineer, by the length of the bottom course measured along the axis of the pavement.

The price bid for the respective items shall include the furnishing, placing, filling, rolling of the material and all labor and incidental expenses necessary to complete the work.

Item 46 — Concrete Foundation for pavement

46.1. Under this item the Contractor shall furnish and place upon a properly prepared subgrade, concrete foundation for pavement of the thickness shown upon the plans or ordered by the Engineer.

46.2. Concrete foundation shall not be placed on any subgrade until the subgrade has been properly drained, thoroughly rolled and compacted, and is true to line and grade in horizontal and transverse cross-section.

46.3. Concrete shall consist of a mixture of Portland cement, No. 2 or No. 3 sand and broken stone or gravel. The coarse aggregate shall consist of a well mixed product of No. 2 and No. 3 stone or No. 2 and No. 3 gravel. The fine aggregate shall consist of No. 2 or No. 3 sand. All of these materials shall conform in all respects to the requirements given under "Materials of Construction," pages 372 to 377. All specifications relating to second-class concrete shall apply to work done under this item, in so far as they are not inconsistent with the special specifications given below.

46.4. The concrete shall be mixed in the proportions of one volume of cement to two and one half volumes of sand and five volumes of broken stone or gravel. The relative proportions of fine and coarse aggregate may be varied slightly, as a result of tests for voids by the Engineer, to the end that the resulting concrete shall be as dense as possible. The concrete shall in all cases approximate a $1:2\frac{1}{2}:5$ mix.

46.5. The concrete shall be mixed in approved mechanical batch mixers. Mixing shall be continued through at least 12 revolutions and until every particle is coated with mortar and until the batch is of uniform color and consistency. After the materials are once wetted the work shall proceed rapidly until the concrete is in place. The quantity of water used shall be as directed by the Engineer and suitable measuring tanks shall be provided by the Contractor so that the same amount of water may be used in the separate batches.

46.6. Before any concrete is placed, the subgrade shall be sprinkled sufficiently to dampen it, but a muddy condition shall not be allowed. As soon as possible after mixing, the concrete shall be deposited in place and thoroughly spaded and rammed so as to bring the mortar flush to the surface. Especial care shall be taken to keep the concrete uniform and to prevent pockets of stone or mortar.

46.7. The surface, when completed, shall conform to the lines and grades shown upon the plans, and shall be free from depressions or irregularities. No stone shall project above the general surface. All ramming and shaping shall be done before the concrete has taken its initial set.

46.8. When the work is stopped for any reason a vertical joint shall be put in and the work completed up to this joint.

46.9. No concrete foundation for pavement shall be laid when the temperature falls below 35° F.

46.10. As soon as the concrete has taken its initial set the surface shall be covered with a one-inch layer of suitable material and this shall be kept moist for a period of at least seven days. For covering concrete foundations on which a sand cushion is called for, the sand cushion may be used for the cover coat if the contractor so elects; in case this is done the sand cushion shall be put in acceptable condition before preparing for laying the blocks; any portions which have become excessively dirty shall be removed and replaced with acceptable material to the satisfaction of the Engineer.

In those cases where material other than sand cushion is used as a cover coat it shall be cleaned off after a period of ten days.

46.11. The quantity to be paid for under this item shall be the number of cubic yards of concrete foundation for pavement incorporated in the work in accordance with the plans or as directed by the Engineer.

The price bid shall include the furnishing and placing of all materials; all mixing, tamping, finishing, and all labor, appliances and incidental expenses necessary to complete the work. The amount to be estimated shall be computed by multiplying the cross-section of concrete foundation as shown upon the plans or ordered by the Engineer by the total length of concrete foundation measured along the axis of the pavement.

TOP COURSE

Item 47 — Top Course — Water Bound Macadam — Gravel

47.1. Under this item the Contractor shall furnish and place upon the bottom course, gravel of an approved character to form the top course.

47.2. The top course shall consist of approved gravel of the character hereinbefore specified and of the thickness shown on the plans, together with the binder necessary to properly fill and bind the course. For this purpose gravel of No. 3 size with, when approved by the Engineer, a certain amount of No. 2 size, may be used. Run of bank gravel shall not be used except by written permission of the Division Engineer; this permit must be given in advance, shall specify the locality from which it is to be taken, and contain a proviso that if the material should at any time become unsatisfactory its use shall at once cease and proper material be furnished without additional recompense even if it has to be imported. A copy of any such permit must be filed with the State Highway Commission, and on this permit must be the written and signed acceptance of all the conditions by the Contractor.

47.3. The gravel shall be spread evenly upon the bottom course, using cubical blocks for gauging, to such a depth as to insure the required thickness after it shall have been thoroughly rolled and compacted with an approved roller weighing 10 to 12 tons. Care shall be exercised to prevent any depressions or surface irregularities after rolling the gravel and binder.

47.4. When the gravel consists of screened material the binder shall consist of a mixture of the sand screened out and the No. 1 size, with enough clay added when necessary to make a percentage of 12 to 17, but not to exceed 17 per cent. The binder shall be added as directed by the Engineer and thoroughly swept into interstices thereof until they are filled. After sprinkling the surface it shall be thoroughly rolled. The adding of binder where necessary and the sweeping, sprinkling and rolling shall continue until the course is compacted. The pavement shall then be opened to traffic and shall be in a first-class and satisfactory condition at the time of its acceptance.

47.5. When the gravel consists of run of the bank the binder shall be the fine particles contained in the material in its natural state except that when so ordered in writing by the division Engineer a small percentage of clay or loam may be added, when necessary to properly bind the course.

The particles shall be of such size as will pass through a $3\frac{1}{2}$-inch circular hole, and shall be well graded. Gravel shall be of such nature that the material passing a $\frac{1}{4}$-inch screen shall not be more than five per centum in excess of the voids in the remaining material after its separation therefrom. Should at any time during the work and for any reason the gravel fail to maintain suitable proportions of the coarse and fine particles, the Contractor shall by the addition of selected material and satisfactory manipulation produce a top course meeting the above requirements.

Care shall be taken to keep the large stone away from the surface.

After sprinkling the surface it shall be thoroughly rolled. Additional material forbinder shall be added where necessary and the sprinkling and rolling shall continue until the course is compacted. The pavement shall then be opened to traffic and shall be in a first-class and satisfactory condition at the time of its acceptance.

47.6. The quantity to be paid for under this item shall be the number of cubic yards of compacted material in place in the completed course. The amount will be computed by multiplying the finished cross-section of the top course as shown on the plans or ordered by the Engineer, by the length of the top course measured along the axis of the pavement.

The price bid under this item shall include the furnishing, placing, rolling, filling, and puddling of the material, and all labor, material and incidental expenses necessary to complete the work.

Gravel or screenings remaining loose on the surface after the work is completed shall not be estimated as a part of the depth of the top course, but payment therefor shall be included in the price bid for this item.

Item 48 — Top Course — Water Bound Macadam — Broken Stone

48.1. Under this item the Contractor shall furnish and place upon the bottom course broken stone to form the top course.

48.2. The top course shall, except as noted below, consist of No. 3 broken stone as shown on the plans and of the thickness shown

thereon, together with the binder necessary to properly fill and bind the course. The binder shall consist of screenings and No. 1 stone mixed.

48.3. The No. 3 stone shall be spread evenly upon the bottom course, using cubical blocks for gauging, to such a depth as to insure the required thickness after it shall have been thoroughly rolled and compacted. Care shall be used in the reading of the stone that no irregularities in the contour shall develop in the rolling; every such irregularity that does occur the Contractor shall remove before adding the smaller material. The rolling shall be done with a 10 to 12 ton self-propelled roller of approved pattern, and shall be continued until the layer of stone does not creep or wave ahead of the roller.

After the stone has been compacted to the satisfaction of the Engineer, a light coating of binder shall be spread on dry by shoveling from piles previously placed alongside the pavement, and immediately swept in and thoroughly rolled. Care must be taken throughout to add the binder only in light coatings and to thoroughly sweep each coating in order that the maximum amount of binder may be worked in to fill the voids. The spreading and sweeping and rolling shall be continued until no more binder will go in dry, after which the macadam shall be sprinkled until saturated, the sprinkler being followed by the roller. If the subgrade should become wet to such an extent that the pavement becomes unstable and waves under the roller, the roller shall be taken off and this portion left to dry out before puddling is resumed.

More screenings shall be added where necessary, and the sweeping, sprinkling, and rolling shall continue until a grout has been formed that shall fill all the voids and be pushed into a wave by the wheels of the roller. After the wave of grout has been produced over the whole section of the macadam this portion shall be left to dry out, after which it shall be opened to traffic. The macadam shall be repuddled and back-rolled on succeeding days as much as may be necessary to secure satisfactory results. The macadam shall then be covered with a wearing carpet of screenings at least three-eighths of an inch thick; this wearing carpet shall be maintained and renewed until the whole road is accepted. During all the working hours when the roller is not needed for rolling the fills, subgrade, shoulders, and unfinished courses of the pavement, it shall be employed in back-rolling the earlier portions of the macadam.

48.4. The quantity to be paid for under this time shall be the number of cubic yards of compacted material in place in the completed course. The amount to be estimated shall be computed by multiplying the finished cross-section of the top course as shown on the plans or ordered by the Engineer, by the length of the top course measured along the axis of the pavement.

The price bid shall include the furnishing, placing, rolling, filling and puddling of the material, and all labor, material and incidental expenses, necessary to complete the work.

No. 1 stone or gravel, chips or screenings remaining loose on the surface after the work is completed shall not be estimated as a part

of the depth of the top course, but payment therefor shall be included in the price bid for this item.

Item 49 — Cleaning Old Pavement

49.1. The purpose of the work called for under this item is to prepare an old macadam or old concrete surface for the application of a new top course or a wearing carpet.

49.2. Under this item the Contractor shall clean the old macadam or concrete surface by the use of seal hand brooms or by the use of mechanical sweepers of approved type, as directed by the Engineer, so as to completely uncover but not dislodge the embedded stones of the pavement.

All mud, dust, and other dirt so swept off shall then be removed and deposited in such places and in such manner as the Engineer may direct.

49.3. Ruts and depressions of a greater depth than one inch below the general surface of the pavement shall be completely swept out by hand brooms until all loose material has been removed and the embedded stones are fully uncovered.

This operation of cleaning out the ruts and depressions and filling them with thoroughly compacted stone and binder to the general level of the surface, shall precede the general operation of cleaning the macadam surface.

49.4. The amount to be paid for under this item shall be the actual number of square yards of old macadam or concrete, including ruts and depressions, cleaned in accordance with the above sections and to the satisfaction of the Engineer.

The price bid shall include all labor, tools, appliances, the removal of material cleaned from the surface, and all other expenses incidental thereto.

Item 50 — Scarifying and Reshaping Old Macadam

50.1. The purpose of the work under this item is to prepare old macadam pavement for the application of a top course.

50.2. Under this item the Contractor shall thoroughly scarify the old macadam by hand picking or by means of a mechanical scarifier of approved type. Unless specifically authorized by the Engineer, the use of a roller with spiked wheels will not be permitted.

The loosened stones shall then be forked or raked over as directed by the Engineer, after which the macadam shall be compacted by rolling with a self-propelled roller weighing not less than 10 tons until an even and firm surface is produced. If necessary in order to satisfactorily compact the stones, the macadam shall be sprinkled during the process of rolling.

50.3. The quantity to be paid for under this item shall be the actual number of square yards, scarified, reshaped, rolled and compacted to the satisfaction of the Engineer, and the price stipulated shall include all labor, appliances and expenses incidental thereto.

Item 51 — Surface Treatments with Bituminous Material

51.1. Under this item the Contractor shall apply bituminous material and shall apply broken stone or gravel of specified sizes as a wearing carpet to a new or old pavement of macadam, concrete, or any other substance or type, as shown on the plans or ordered by the Engineer.

51.2. If the pavement to be treated is a newly built macadam or concrete, after it shall have become thoroughly dried and hardened, it shall be swept clean of all dust, dirt or other loose material; if ordered by the Engineer, the sweeping of the macadam shall be continued until the voids are exposed in the surface to a satisfactory depth, not exceeding one-half inch. The price bid, under this item, shall include the aforesaid cleaning of the pavements.

If the pavement to be treated is an old macadam or old concrete, the cleaning shall be paid for under Item "Cleaning Old Pavement."

51.3. After the pavement shall have been cleaned to the satisfaction of the Engineer, and when dry, the bituminous material shall be uniformly sprayed over the surface by means of an approved pressure distributor. The bituminous material for hot application shall be heated to a temperature between 250 degrees and 350 degrees F. as required, and when tar is used, it shall be heated to a temperature between 200 degrees and 250 degrees F. as required.

The amount of bituminous material to be used in any one application shall not be less than one-sixth nor more than one-half gallon per square yard, the precise quantity depending upon the character of the pavement, the materials and the local conditions. The Contractor shall, therefore, be subject entirely to the direction of the Engineer in this respect.

51.4. The bituminous material applied as above specified shall then be immediately covered, while soft, with a uniform layer of approved broken stone of No. 2. or No. 1 size, after which the stone shall be rolled with a self-propelled roller of approved weight. If ordered by the Engineer another application of bituminous material shall then be made to be followed by an application of approved No. 2 stone or approved No. 1 stone, and again rolled to the satisfaction of the Engineer.

The quantity of No. 2 stone and of No. 1 stone to be used shall be sufficient to completely cover the bituminous material and shall be spread in two or more thin applications, the roller being used after each spreading. The total amount of stone to be used after each application of the bituminous material being that which will become imbedded under the pressure of the roller. The final application of the stone shall be of No. 1 size.

51.5. Gravel, which has been tested and approved for use, may be substituted for broken stone if screened to produce particles corresponding with No. 2 and No. 1 sizes.

51.6. No bituminous material for surface treatment shall be placed between October 15th and May 15th, except by written permission of the Engineer, nor when the air temperature on the work is below 50 degrees F., nor when the pavement is damp or in an otherwise unsatisfactory condition.

51.7. Under this item the Contractor shall be paid for the number of gallons of bituminous material furnished in and incorporated in the work in accordance with these specifications and the orders of the Engineer. Bituminous material, that has been wasted or that has been rendered unfit for use by over-heating or by long-continued heating, shall not be paid for. For purposes of measurement, a gallon shall be a volume of 231 cubic inches and measurement shall be based on the volume of the bituminous material at a temperature of 60 degrees F.

The price bid shall include the furnishing, hauling, heating and applying the bituminous material, and shall also include the spreading, rolling and incorporation of the stone into the wearing carpet.

This item shall not include the furnishing of the No. 1 and No. 2 stone or gravel, nor the delivery of same along the side of the road; these will be paid for under Items Screened Gravel or Broken Stone Loose Measure, respectively.

Item 52 — Top Course Bituminous Macadam — Penetration Method

52.1. Under this item the Contractor shall furnish and lay a broken stone top course composed of fragments of the specified sizes, and incorporate therewith bituminous material introduced from the surface by means of an approved pressure distributor.[1]

52.2. After the bottom course shall have been completed to the satisfaction of the Engineer, a course of approved No. 3 broken stone shall be evenly spread thereon in such quantity that after the application of the bituminous material and broken stone of smaller sizes, hereafter specified, the final compacted thickness of the top course shall be as called for on the plans or ordered by the Engineer.

The No. 3 stone shall then be smoothed out by passing over it a few times a self-propelled roller weighing approximately 10 tons, after which bituminous material of the kind specified in the proposal, heated to a temperature between 250 degrees and 350 degrees Fahrenheit if asphalt is used, and between 200 degrees and 250 degrees if tar is used, shall be evenly spreading over the surface. The quantity of bituminous material to be used in the first application shall be the amount ordered by the Engineer, which will approximate $1\frac{3}{4}$ gallons per square yard for a top course 3 inches thick, with a proportional reduction in the quantity for thinner courses.

The surface shall then be immediately covered with a layer of approved No. 2 broken stone, after which it shall be compacted with a self-propelled roller weighing approximately 10 tons; during the rolling process, additional No. 2 broken stone shall be applied and broomed about until the voids in the No. 3 stone are entirely filled.[2] The rolling shall be continued until the course of stone is thoroughly

[1] Hand spreading from pots or hods is more satisfactory for the first coat but not for the flush coat.

[2] Too much rolling is injurious while the oil is hot; better results are obtained by waiting till the next day to compact; the course should be rolled early in the morning for 10 days and gradually hardened down.

compacted and its surface is true and even to the established grade and conforms in all respects to the requirements specified for finishing and testing the surface of "Top Course Bituminous Macadam, Mixing Method — Type 1."

52.3. After this portion of the work shall have been completed to the satisfaction of the Engineer, all loose stone shall be swept from the surface and a sealing coat of one-half gallon of bituminous material per square yard shall be applied by means of an approved pressure distributor. After this it shall be immediately covered with approved No. 1 broken stone, spread and broomed about by experienced workmen, and again rolled; the rolling shall be continued and additional No. 1 stone shall be applied until a smooth, uniform surface is produced.

52.4. Before being opened to traffic a layer of No. 1 broken stone approximately one-half inch thick shall be spread loose on the surface for wearing course.

52.5. The quantity to be paid for under this item shall be the number of cubic yards of compacted material in place in the completed course. The amount to be estimated shall be computed by multiplying the finished cross-section of the top course, as shown upon the plans or ordered by the Engineer, by the length of the top course measured along the axis of the pavement.

The price bid shall include the heating and placing of the bituminous material, the furnishing, placing, rolling and filling of the broken stone, and all labor, materials, and incidental expenses necessary to complete the top course.

This item shall not include the furnishing and delivery of the bituminous material; such furnishing and delivering will be paid for under the item covering such material.

No. 1 broken stone or gravel, chips or screenings remaining loose on the surface after the work is completed shall not be estimated as a part of the depth of the top course, but payment for these shall be included in the price bid for item 52.

Item 53 — Top Course — Bituminous Macadam — Mixing Method. Type 1

53.1. Under this item the Contractor shall construct a top course of broken stone mixed with a bituminous material, upon a previously constructed bottom course of concrete, broken stone, quarry or field stone, or gravel. The surface laid shall be in conformity with the lines and grades shown upon the plans or ordered by the Engineer. A smooth finished surface will be insisted on free from irregularities and waviness. The entire top course shall consist of a wearing course finished over with a flush or sealing coat.

53.2. The broken stone used in this course shall be of approved material. When the top course is to be 2 inches or less in thickness in the completed work, the stone shall be of No. 2 size. When the top course is to be over 2 inches in thickness in the completed work, No. 2 and No. 3 stone shall be used, proportioned as directed by the Engineer. The sealing coat therefor shall be of stone of No. 1 size.

53.3. Gravel of approved quality and corresponding to the same sizes as broken stone may be used in the top course. If used, it shall conform to the general requirements for broken stone and gravel for water-bound and bituminous macadam work.

53.4. The broken stone for the wearing course shall be heated, before entering the mixer, to between 225 degrees Fahrenheit and 300 degrees Fahrenheit in revolving dryers of an approved type. The stone shall be continuously agitated during the heating.

53.5. The bituminous material to be used in this course shall conform with the specifications for "Bituminous Material A for Mixing Method — Type I."

53.6. The bituminous material shall be heated in kettles so designed as to admit of even heating of the entire mass, with an efficient and positive control of the heat at all times. Bituminous material "A" shall be heated as directed to a temperature between 275 degrees Fahrenheit and 350 degrees Fahrenheit; all material heated beyond 350 degrees Fahrenheit, either before or during mixing with the broken stone, shall be rejected. Bituminous material "T" shall be heated as directed to a temperature between 200 degrees Fahrenheit and 275 degrees Fahrenheit; all bituminous material "T" heated beyond 275 degrees Fahrenheit either before or during mixing with the broken stone, shall be rejected. No tar shall be heated in kettles containing any asphalt cement, and no asphalt cement shall be heated in kettles containing any tar; before changing from one type of material to the other, kettles shall be scrupulously cleaned in order to avoid mixtures of the two; any such Mixtures shall be rejected.

53.7. When thoroughly heated to the proper temperatures, the bituminous material and the broken stone for the wearing course shall be mixed as directed from time to time, using approximately 18 gallons of bituminous material per cubic yard of loose stone. (The amount of bitumen in the completed work shall be from 5 to $7\frac{1}{2}$ per centum of the total weight of the completed course.) The Contractor shall provide approved means for accurately proportioning the mixture. Excess of bituminous material shall be prevented; and any such excess shall be cause for rejection of the course unless satisfactorily corrected previous to laying. The mixer used shall be of satisfactory design, having revolving blades and efficient means for keeping the temperature at the desired point without burning the liquid. The mixing shall continue until every particle of the broken stone is thoroughly coated with the bituminous material and a uniform mixture has been obtained, which when discharged shall have a temperature between 200 degrees and 300 degrees Fahrenheit for bituminous material "A" and between 200 degrees and 250 degrees Fahrenheit for bituminous material "T."

The use of batteries of small batch mixers will not be allowed.

53.8. The bituminous mixture, heated and prepared as specified above, shall be delivered from the mixer to the point of deposition in the pavement, if at a considerable distance, in suitable trucks or wagons, provided with canvas covers for retaining the heat. To prevent undue compacting on long hauls, partitions may be required

for large truck loads. As delivered, the mixture shall have a temperature of at least 150 degrees Fahrenheit. Material having a lower temperature than this shall not be laid in the pavement. The mixture shall be immediately spread over the foundation course by men experienced in such work, so that when rolled it shall have the required thickness and shall be free from surface depressions and irregularities. The paving shall be done as continuously as practicable, to reduce to a minimum the number of joints between hot and cold materials. Such joints shall be constructed in an approved manner. The hot paving mixture shall not be dumped in large masses on the bottom course. It shall be dumped upon platforms and shoveled with hot shovels into position in the pavement.

53.9. The wearing course, placed as above specified, shall be rolled at once, while the material is still warm and pliable, beginning at the edges and working toward the center. Acceptable means shall be provided to prevent the asphalt from sticking to the roller. Rolling shall continue without interruption until all roller marks disappear and the surface shows no further compressibility. Places which the roller cannot effectively reach shall be compressed with hot iron tamps.

53.10. As soon as possible after the compacting of the wearing course, when the surface is clean and dry, a sealing coat of hot bituminous material "A" shall be evenly spread over the wearing course by means of approved pressure distributors. The bituminous material "A" shall be applied at a temperature not less than 275 degrees Fahrenheit nor more than 350 degrees Fahrenheit, at a rate of $\frac{1}{2}$ to $\frac{3}{4}$ gallon per square yard, as directed. A thin and uniform layer of dry, clean No. 1 stone shall be immediately spread over the bituminous material "A" by machines or skilled workmen, sufficient to more than take up all the excess bituminous material "A." The spreading of the No. 1 stone shall not lag more than 20 feet behind the placing of the asphalt coating. The pavement shall then be again thoroughly rolled. The surface of the wearing course shall be kept scrupulously clean until the sealing coat is applied. The Contractor shall not permit any hauling over the surface before the completion of the sealing coat.

53.11. Before placing the sealing coat, the pavement shall be tested with a ten foot straight edge laid parallel with the center line of the pavement, and any depressions exceeding one-half inch shall be satisfactorily eliminated or the pavement relaid.

53.12. Rollers used for the bituminous wearing course and the sealing coat shall be well balanced, self-propelled rollers of satisfactory design, weighing between eight and ten tons. They shall give a compression under the rear roller of between 200 and 350 pounds per linear inch of roll, and shall be provided with an ash pan which shall prevent ashes from dropping upon the pavement.

53.13. No top course bituminous material shall be mixed or placed between October 15 and May 15 except by written permission of the Engineer, nor when the air temperature in the shade is below 50 degrees Fahrenheit, nor when the foundation is damp or otherwise unsatisfactory.

53.14. The Contractor shall provide a sufficient number of accurate, efficient thermometers for determining the temperatures of the bituminous material and the broken stone at all stages of the work.

53.15. The quantity to be paid for under this item shall be the number of square yards of compacted material in place in the completed course. The amount to be estimated shall be computed by multiplying the finished width of the top course as shown upon the plans or ordered by the Engineer, by the length of the top course measured along the axis of the pavement.

The price bid shall include the furnishing (bituminous material excepted), the heating, placing, rolling and compacting of all materials, together with all other labor and incidental expenses necessary to satisfactorily complete the work.

The furnishing of the bituminous material will be paid for under the appropriate item therefor as shown on the proposal sheet.

Item 54 — Top Course — Bituminous Macadam — Mixing Method. Type 2

54.1. Under this item the Contractor will be required to construct a top course consisting of a compacted mixture of broken stone, sand and bituminous material "A" laid to conform to the required grade and cross-section, as shown on the plans and ordered by the Engineer.

54.2. Broken stone for this course shall be of the character specified all of which shall pass a one-half-inch screen and shall be so graded that when combined in a bituminous mixture containing not less than thirty (30) per centum of the sand specified in section 54.3 it shall produce a bituminous mixture coming within the limits specified in section 54.8.

54.3. The sand shall be clean, hard grained and sharp. It shall all pass a ten (10) mesh screen, and shall contain at least fifteen (15) per centum of material retained on a forty (40) mesh screen and at least twenty (20) per centum of material that will pass an eighty (80) mesh screen except as hereinafter provided for. If the sand does not contain the required amount of fine material, approved stone dust may be added to make up the deficiency.

54.4. The bituminous material to be used in this course shall conform with the specifications for bituminous material "A" for Type 2.

54.5. The broken stone and sand shall be heated as directed, before entering the mixer, to between 225 degrees Fahrenheit and 325 degrees Fahrenheit in revolving dryers of an approved type. The broken stone and sand shall be continuously agitated during the heating.

54.6. The bituminous material shall be heated in kettles so designed as to produce an even heating of the entire mass, with an efficient and positive control of the heat at all times. It shall be heated as directed to a temperature between 275 degrees Fahrenheit and 350 degrees Fahrenheit. If heated beyond 350 degrees Fahrenheit either before or during the mixing with the broken stone it shall be rejected.

54.7. The Contractor shall provide a sufficient number of accurate, efficient, stationary thermometers for determining the temperature of the asphalt cement in the kettles.

54.8. When thoroughly heated to the temperature directed, the bituminous material and the broken stone and sand shall be mixed in the following proportions by weight:

Bitumen	from 7 to 11%
Mineral aggregate, passing 200 mesh	from 7 to 11%
Mineral aggregate, passing 40 mesh	from 45 to 55%
Mineral aggregate, passing 10 mesh	from 16 to 25%
Mineral aggregate, passing 4 mesh	from 8 to 15%
Mineral aggregate, passing 2 mesh	less than 10%

the sieves being used in the order named. A mixer shall be used, having revolving blades, and so designed and operated as to produce and discharge a thoroughly coated and uniform mixture of non-segregated broken stone, sand and bituminous material. When discharged the mixture shall have a temperature not more than 325 degrees Fahrenheit and not less than 225 degrees Fahrenheit as directed.

54.9. All defective areas in the cement concrete foundation shall be repaired as directed at least ten (10) days in advance of laying the bituminous concrete. Before laying the bituminous concrete the surface of the foundation shall be dry and thoroughly cleaned.

54.10. The mixture heated and prepared as specified in section 54.8, shall be delivered direct from the mixer to the point of deposition on the foundation in trucks or wagons, provided with canvas covers for retaining the heat. As delivered, the bituminous concrete shall have a temperature of at least 200 degrees Fahrenheit: material having a lower temperature than this shall not be laid upon the foundation. Before the mixture is placed, all contact surfaces of curbs, edgings, manholes, etc., shall be well painted with hot asphalt cement. The hot mixture shall be dumped upon platforms, constructed as directed, and shoveled with hot shovels into position on the foundation. It shall be immediately spread as directed over the foundation course by men experienced in such work, so that when rolled it shall have at no place less than the required thickness and shall be free from surface depressions and irregularities. Joints between hot and cold materials shall be constructed as directed. The paving shall be done as continuously as practicable, to reduce to a minimum the number of such joints.

54.11. Rollers used on the bituminous concrete shall be well balanced, self-propelled, tandem rollers, weighing between seven (7) and eight (8) tons each. Each shall have a compression under the rear roller of between two hundred (200) and three hundred (300) pounds per linear inch of roll, and shall be provided with an ash pan which shall prevent ashes from dropping into the bituminous concrete or sealing coat.

54.12. The surface of the top course shall be tested with a ten (10) foot straight edge laid parallel with the center line of the road

upon any portion of the surface, and any depression or other irregularity exceeding one-half ($\frac{1}{2}$) inch [$\frac{1}{4}''$ is a better limit] shall be satisfactorily eliminated as directed.

54.13. After the pavement has been satisfactorily finished and has thoroughly dried out, Portland cement shall be dusted over the surface in a quantity sufficient to form a complete film over all parts of the pavement. This film shall remain undisturbed by rain or otherwise until it has set; in case of disturbance before setting, it shall be renewed.

54.14. No top course material shall be mixed or placed between October 15th and May 15th, except by written permission of the Engineer, nor when the air temperature in the shade is below 50 degrees Fahrenheit nor when the foundation is damp or otherwise unsatisfactory.

54.15. The quantity to be paid for under this item shall be the number of square yards of compacted material in place in the completed pavement. The amount to be estimated shall be computed by multiplying the width of top course as shown on the plans or ordered by the Engineer, by the length of the top course measured along the axis of the road.

The price bid for this item shall include the furnishing of the sand; the furnishing, crushing and screening of the broken stone; the heating, mixing, placing and rolling of the broken stone, sand and bituminous material, and the cement film and all work and expense incidental to the completion of the work except the furnishing of the bituminous material, which shall be paid for under the item BITUMINOUS MATERIAL "A" FOR MIXING METHOD, TYPE 2.

Item 55 — Bitulithic Pavement

55.1. Under this item the Contractor shall furnish the necessary stone, bituminous material, machinery, labor and other equipment, and shall construct upon a properly prepared foundation a bitulithic pavement composed of an accurately proportioned aggregate of carefully graded broken stone properly heated and mixed with separately heated Warren's Puritan Brand bitulithic cement, placed and rolled and covered with Warren's quick drying bituminous flush coat composition, followed by two coats of hot stone chips thoroughly rolled into the surface.

55.2. The several grades and sizes of mineral aggregate shall be accurately measured in proportions previously determined by laboratory tests to give the best results; that is, the most dense mixture of mineral aggregate and one having inherent stability; heated in a rotary mechanical heater so designed as to keep each batch by itself until heated, or after heating the stone in a rotary mechanical heater to a temperature of about 250 degrees Fahrenheit, it shall be elevated and passed through a rotary screen, having sections with various sized openings. The difference in the width of openings in successive sections shall not exceed one-fourth ($\frac{1}{4}$) inch in sections having openings smaller than one-half ($\frac{1}{2}$) inch, and shall not exceed one-half ($\frac{1}{2}$) inch, in sections having openings greater than one-half ($\frac{1}{2}$) inch.

The several sizes of stone thus separated by the screen sections shall pass into a bin containing sections or compartments corresponding to screen sections. From these compartments the stone shall be drawn into a weighing-box, resting on a scale having seven beams. The stone from these compartments shall be accurately weighed, using the proportions which have been previously determined by laboratory tests to give the best results; that is, the most dense mixture of mineral aggregate, and one having inherent stability. If the crushed stone in the wearing course does not provide the best proportions of fine-grained particles, such deficiency must be supplied by the use of not to exceed 25 per centum hydraulic cement, pulverized stone, or very fine sand.

55.3. The mineral aggregate, composed of differing sizes accurately measured or weighed as above, shall pass into a "twin pug," or other approved form of mixer. In this mixer shall be added a sufficient quantity of Warren's Puritan Brand, bituminous water-proof cement, or bitulithic cement, to thoroughly coat all the particles of stone and to fill all voids in the mixture. The bituminous cement shall, before mixing with the stone, be heated to between 200 degrees and 250 degrees Fahrenheit, and the amount used in each batch shall be accurately weighed and used in such proportions as have been previously determined by laboratory tests to give the best results — that is, to coat all particles of stone and fill the voids in the mineral aggregate. The mixing shall be continued until the combination is a uniform bituminous concrete. In this condition it shall be hauled to the street, and there spread on the prepared foundation to such a depth that, after thorough compression with a steam road roller, it shall have a thickness of two (2) inches. The proportioning of the varying sizes of stone and bituminous cement shall be such, that the compressed mixture shall, as closely as practicable, have the density of solid stone.

55.4. After rolling the wearing surface, there shall be spread over it, while it is still warm, a thin coating of Warren's Quick Drying Bituminous Flush Coat Composition, by means of a suitable flush coat spreading machine, so designed as to spread quickly over the surface a uniform thickness of flush coat composition. This spreading machine shall be provided with a flexible spreading band and an adjustable device for regulating, to any desired amount, the quantity and uniformity of flush coat composition to be spread.

There shall be spread over the flush coat composition, in at least two coats, fine particles of hot crushed stone, in sufficient quantity to completely cover the surface of the pavement. These stone chips shall be spread by means of a suitable stone spreading machine, so designed as to provide a storage receptacle of at least five (5) cubic feet capacity and to rapidly and uniformly cover the surface of the pavement with the desired quantity of stone. This spreading machine shall be provided with an adjustable attachment for regulating uniformly the quantity of stone spread at each operation. The hot stone chips shall be immediately and thoroughly rolled into the surface until it has become cool. The purposes of the flush coat composition and the fine particles of hot crushed stone are to not

only fill any unevenness in the surface, but also to make the surface waterproof and gritty, thus providing a good foothold for horses.

On grades a mineral flush coat may be used in place of the liquid flush coat.

55.5. Warren Bros., owners of the patents used in the construction of Bitulithic pavement, have filed with the State Commission of Highways a properly executed binding agreement to furnish any contractor to bid for the work all the necessary surface material mixed and ready for use, and bituminous flush coating cement necessary for coating the wearing surface, delivered on wagons of the Contractor at the mixing plant (which will be located within three miles of the point of use) at a stipulated price per square yard for each contract. Such price for Bitulithic pavement mixture and flush coating composition will include a license to use all the patents required in the construction of the pavement as herein specified.

The filing of a bid under these specifications will be construed as an acceptance of the terms of the license agreement filed by the Warren Bros. Company, at the price fixed in said agreement, which is on file with the secretary of the Commission.

55.6. The quantity of pavement to be paid for under this item shall be the number of square yards of Bitulithic pavement placed in accordance with the plans, or as directed by the Engineer. The bid price shall include the furnishing and placing of all materials, the mixing, spreading, rolling and all labor and incidental expenses necessary to complete the work.

GENERAL SPECIFICATIONS FOR AMIESITE PAVEMENT

Foundation. The excavation, filling or embankment, drainage and rolling of the sub-base shall be in full accordance with the standard specifications for street or highway paving before placing the foundation, the depth and nature of which is governed by existing conditions of the sub-grade.

The foundation, whether in re-surfacing or new work, shall be, before applying the Amiesite, even and compact and swept clean of all loose dirt and foreign material. New stone, if put on, shall be thoroughly bonded with screenings, sprinkled and rolled hard and uniformly. The foundation must be uniform and be brought up to a true and even grade, parallel to and   inches below the elevation of the finished surface of the street or road.

Application. The bottom course shall be spread in a uniform layer, using blocks or strips to insure an even distribution, then rolled. (Size) Stone used in Amiesite Bottom Course-Graded — $\frac{3}{4}''$ to $1\frac{1}{4}''$. If any depressions appear, due to foundation not being firm or any other reason, they must be filled with Amiesite and rolled until surface is even and to grade desired.

After the preliminary rolling, the Amiesite top course, made of stone graded from $\frac{1}{4}''$ to $\frac{1}{2}''$ in size, shall be applied, not less than one inch ($1''$) deep, loose measurement, and raked to an even depth so as to cover the underlying Amiesite and fill the voids. In no case

shall the bottom course be spread over 300′ in advance of the top course, nor shall over 50′ be left uncovered during the night.

The compressed depth of finished Amiesite surface shall be: Preferably not less than $2\frac{1}{2}$ inches.

Rolling. After the top course has been evenly spread to a true grade, the surface shall be rolled with a standard ten ton road roller until the material is thoroughly compacted and ceases to creep in front of the roller. In rolling the roller must start from the sidelines of the street or road and work towards the center. Care must be taken that the shoulders are firm and solid, as otherwise the surface will iron out to a feather edge and crack. No rolling shall be done unless the Amiesite is free from water.

Surface Finish. After rolling as called for above, clean, sharp sand or stone dust (Linestone where obtainable) shall be spread in a thin layer and the road may then be immediately thrown open to traffic.

General. No Amiesite shall be spread when the road-bed contains depressions holding water. The Amiesite must at all times be kept clean. Dirt or other foreign material must not be allowed to mix with, under, or on the Amiesite while being unloaded from cars, spread and rolled.

Should the bottom course become coated or partly coated with dust or dirt before the top course can be applied, the part thus coated must be swept and then given a light application of bituminous cement, that can be applied in a thin coating from a sprinkling pot so constructed that a thin and uniform application can easily be applied.

The Amiesite may be steamed to facilitate its unloading from the cars. Steam pressure shall not exceed fifteen pounds to the square inch. The Amiesite should not be steamed more than fifteen minutes in any one place. This shall be done under the supervision of the inspector in charge.

The Amiesite shall be unloaded from wagons upon iron sheets or boards, so as to insure the material being kept clean and being spread uniformly.

Cross rolling shall be done, when ordered, to equalize the bond and prevent waves in the surface. Care must be taken that the bottom course is not rolled down hard before the top course is applied.

The finished surface of the Amiesite after rolling shall be kept $\frac{1}{2}''$ higher than any permanent elevation, depending upon the traffic to ultimately compress or pound it down to grade.

Grading slopes or shoulders shall not be carried on after the Amiesite course is started until completion of roadway.

The street or road shall be closed to traffic when the Amiesite surface is being applied.

Item 56 — Hassam Compressed Concrete Pavement

56.1. Under this item the Contractor shall furnish all materials for and place upon a properly prepared sub-grade or sub-bottom course Hassam Compressed Concrete Pavement of the thickness shown upon the plans or ordered by the Engineer.

56.2. Hassam Compressed Concrete Pavement will be placed on the

sub-grade or on the sub-bottom course and shall not be placed until these are in first-class condition as required for macadam pavement.

56.3. Hassam Compressed Concrete Pavement shall consist of a graded No. 3 and No. 4 stone, of an approved quality, spread evenly and gauged by the use of cubical blocks; after rolling and thoroughly compacting with a 10-ton roller, it shall have the required depth and shall conform to the established lines, grades and cross-sections. Where any depressions or irregularities develop in rolling the surface shall be forked over and material added or taken away to the end that a smooth surface shall be provided after re-rolling.

56.4. After the rolling has been satisfactorily completed and the surface of the broken stone has been brought to the required uniform surface, and before there is any displacement of the stone, the voids shall be filled with a grout consisting of one part Portland cement and two parts of approved sand. The sand shall be of such sizes that it will not separate readily from the cement, when placing the grout, and any batch of grout, when being placed, shall at all times be of a uniform product and of such consistency that it will flow readily but shall not be so wet as to cause a separation of the cement and sand. The rolling shall be continued during the process of grouting and until all the voids are filled.

56.5. The grout shall be mixed in a Hassam Grout Mixer or other mechanical mixer which will properly mix the ingredients and from which they can be deposited without a separation of the cement and sand.

56.6. Immediately after the voids shall have been filled with grout, a thin layer of No. 1 broken stone or fine aggregate shall be spread over the entire surface and rolled until the grout flushes to the surface.

56.7. After placing the surface stone the surface shall not be worked upon or disturbed for a period of ten days, during which time the surface shall be kept thoroughly wet.

56.8. Any cracks either longitudinal or transverse which develop before the acceptance of the work shall be thoroughly cleaned out and filled with acceptable bituminous material.

56.9. The quantity to be paid for, under this item, shall be the number of cubic yards of Hassam Compressed Concrete Pavement incorporated in the work in accordance with the plans or as directed by the Engineer.

The price bid shall include the furnishing and placing of all materials, all grouting, rolling, forms and all labor, appliances, royalties and incidental expenses necessary to complete the work. The amount to be estimated shall be computed by multiplying the cross-section of concrete pavement as shown upon the plans or ordered by the Engineer, by the total length of pavement measured along the axis of the pavement.

Item 57 — Cement Concrete Pavement

57.1. Under this item the Contractor shall furnish and place upon a properly prepared sub-grade or sub-bottom course, concrete pavement of the thickness shown upon the plans or ordered by the Engineer.

57.2. Concrete pavement will be placed on the sub-grade or on the sub-bottom course, and shall not be placed until these are in first-class condition, as required for macadam pavement.

57.3. Concrete shall consist of a mixture of Portland cement, No. 1 sand, and broken stone or gravel. All these materials shall conform in all respects to the requirements given under "Materials of Construction," and all the specifications relating to first-class concrete shall apply to work done under this item, in so far as same are not inconsistent with the special specifications given below.

57.4. The concrete shall be mixed in the proportions of one volume of cement to four and one-half volumes of sand and broken stone or gravel. The volumes of sand and broken stone or gravel, shall be measured separately in approved hoppers. The relative proportions of fine and coarse aggregate will be varied slightly, as a result of tests for voids by the Engineer, to the end that resulting concrete shall be as dense as possible. The concrete shall in all cases approximate at $1 : 1\frac{1}{2} : 3$ mix.

57.5. The coarse aggregate shall consist of a well-mixed product of No. 2 and No. 3 stone or No. 1 and No. 2 gravel. Gravel shall not be used except when it has been submitted by the Division Engineer to the Bureau of Tests, has been approved by the Bureau of Tests, and its use has been approved by the First Deputy Commissioner in writing, — and then only under the restrictions laid down under "Materials of Construction." The fine aggregate shall consist of No. 1 sand.

57.6. The concrete shall be mixed in approved mechanical batch mixers. Mixing shall be continued through at least 12 revolutions and until every particle is coated with mortar and until the batch is of uniform color and consistency. After the materials are once wetted the work shall proceed rapidly until the concrete is in place. The quantity of water used shall be as directed by the Engineer and suitable measuring tanks shall be provided by the Contractor so that the same amount of water may be used in the separate batches. No concrete pavement shall be laid when the temperature falls below 35° F.

57.7. Substantial forms shall be placed along the edge of the concrete pavement and shall be set and held true to line and grade.

57.8. Before any concrete is placed, the sub-grade shall be sprinkled sufficiently to dampen it but a muddy condition shall not be allowed. As soon as possible after mixing, the concrete shall be deposited in place and thoroughly spaded and screeded so as to bring the mortar flush to the surface. Especial care shall be taken to keep the concrete uniform and to prevent pockets of stone or mortar.

57.9. Heavy screeds cut to the lines required for the finished surface and resting upon the side forms shall be used for consolidating and screeding the concrete, and the surface, when completed, shall conform to the lines and grades shown upon the plans, and shall be free from depressions or irregularities. No stone shall project above the general surface. All shaping and screeding shall be done before the concrete has taken its initial set. Any concrete

which has not been shaped and finished previous to the time of initial set, shall be removed for the full depth of the roadway and replaced with satisfactory concrete.

57.10. If a satisfactory finish cannot be obtained with the screed, the screeding shall be immediately followed, and before the cement has taken its initial set, by rubbing down with a wooden float. The men employed for this work shall be competent and experienced and shall work from a platform which rests on the forms or shoulders. The surface, when finished, shall be such that no water will stand on the finished pavement. It shall then be slightly roughened by brooming.

57.11. As soon as the concrete has taken its initial set the surface shall be covered with a one-inch layer of sand or other suitable material of which the shoulders are to be constructed and this shall be thoroughly sprinkled every morning and night, and more often if necessary, so that it will be kept moist for a period of ten days after placing; the material shall then be cleaned from the surface and the road may be opened to traffic if so directed by the Engineer.

57.12. The concrete shall be deposited in sections 30 feet in length, and at the end of each section expansion joints of the type shown on the plans shall be placed. After starting any section, an effort shall be made to complete it at one operation. If for any reason this cannot be done, a vertical joint shall be made when the work is stopped and the work completed up to this joint.

57.13. Any cracks, either longitudinal or transverse, which develop before the acceptance of the work, shall be thoroughly cleaned out and filled with acceptable bituminous material.

57.14. The quantity to be paid for under this item shall be the number of cubic yards of concrete pavement incorporated in the work, in accordance with the plans or as directed by the Engineer.

The price bid shall include the furnishing and placing of all materials; all mixing, screeding, finishing, forms, expansion joints and all labor, appliances and incidental expenses necessary to complete the work. The amount to be estimated shall be computed by multiplying the cross-section of concrete pavement as shown upon the plans or ordered by the Engineer by the total length of pavement measured along the axis of the pavement.

Item 58 — Lignin or Sulphite Liquor

58.1. Under this item the Contractor shall furnish and apply lignin or sulphite binder at the rate of one-half gallon of binder (not of the mixture) to the square yard.

58.2. A quart sample, from each carload of the material to be used, shall be submitted to the Bureau of Tests for acceptance before it may be used.

This material shall be a neutral or basic liquor secured by the extraction of lignin from organic matter. It shall be concentrated by evaporation at a temperature not exceeding 210 degrees Fahrenheit until it has a specific gravity at 77 degrees Fahrenheit of not less than 1.23. When concentrated to a constant weight at 212

degrees Fahrenheit, it shall have a residue of not less than 45 per cent. It shall contain not more than 9 per cent of ash. It shall be 99.5 per cent soluble in cold water.

58.3. After the road has been thoroughly filled and brought to a puddle with water, the application of lignin or sulphite binder shall commence and the puddle continued, using a mixture of one part binder to not less than three parts water. This puddling shall continue until the road has received at treatment for its full width of one-quarter gallon of the lignin (not of the mixture) to the square yard. After the roadway has set, but not entirely dried out, the balance of one-quarter gallon of the lignin to the square yard shall be applied to 80 per cent of the width of roadway, using a mixture of one part lignin to two parts water.

58.4. Lignin or sulphite binder shall be applied to the roadway by means of an improved sprinkler which can be regulated so that a uniform distribution is obtained and so that not over one-half of the required amount of binder shall be spread to the square yard on each trip of the sprinkler. The sprinkler shall be equipped with necessary brooms so arranged as to sweep forward any excess material that does not immediately penetrate into the surface.

58.5. The quantity of material to be paid for under this item shall be the actual number of gallons of lignin binder, measured before dilution, actually applied and incorporated in the work to the satisfaction of the Engineer. Binder that has been wasted or that has been applied not in accordance with the requirements of this specification or the orders of the Engineer, shall not be included in this item for payment. The price bid shall include the cost of furnishing, hauling, applying and all necessary appliances and expenses incidental thereto.

Item 59 — Wood Block Pavement

59.1. Under this item the Contractor shall furnish and place upon a properly prepared foundation wood block of the quality specified where shown upon the plans or ordered by the Engineer.

This pavement shall be placed upon the old macadam, old concrete pavement, new concrete foundation or on other foundation as shown on the plans and ordered by the Engineer.

59.2. The blocks shall be from 6 to 9 inches long and shall average 8 inches; they shall be 3 inches in depth and from 3 to 4 inches in width; but all blocks in one piece of pavement shall be of uniform width. No variation greater than $\frac{1}{16}$-inch shall be allowed in the depth and $\frac{1}{8}$-inch in the width of the blocks.

59.3. Blocks shall be made from Southern yellow pine, North Carolina pine, Norway pine, black gum or tamarack; only one kind of wood, however, shall be used in one piece of pavement.

Yellow pine block shall be made from what is known as Southern yellow pine, well manufactured, full size, saw butted, all square edges, and shall be free from the following defects:

Unsound, loose and hollow knots, worm holes and knot holes, through shakes and round shakes that show on the surface. In

yellow pine timber the annular rings shall average not less than six to the inch and shall be in no case less than four to the inch, measured radially.

Norway pine, gum, North Carolina pine and tamarack block shall be cut from timber that is first-class in every respect, and shall be of the same grade as that defined for the Southern yellow pine.

59.4. The creosote oil with which the blocks shall be treated shall conform to either of the following specifications, designated as "A" and "B."

The preservative to be used under this specification shall be a product of coal gas, water gas or coke oven tar, which shall be free from all adulterations and contain no raw or unfiltered tars, petroleum compounds, or tar products obtained from processes other than those stated.

Specification "A"

The specific gravity shall not be less than one and eight-hundredths (1.08) nor more than one and fourteen hundredths (1.14) at a temperature of thirty-eight (38) degrees centigrade.

Not more than three and one-half ($3\frac{1}{2}$) per centum shall be insoluble by continuous hot extraction with benzol and chloroform.

On distillation, which shall be made exactly as described in Bulletin 65 of the Railway Engineering and Maintenance of Way Association, the distillate, based on water free oil, shall not exceed one-half ($\frac{1}{2}$) of one (1) per centum at one hundred and fifty (150) degrees centigrade, and shall not be less than thirty (30) nor more than forty (40) per centum at three hundred and fifteen (315) degrees centigrade.

The oil shall contain not more than three (3) per centum of water.

Specification "B"

It shall be completely liquid at thirty-eight (38) degrees centigrade, and shall have a specific gravity at that temperature of not less than one and three hundredths (1.03) nor more than one and eight hundredths (1.08).

It shall contain not more than two (2) per centum of matter insoluble by hot extraction with benzol and chloroform.

On distillation, which shall be made exactly as described in Bulletin No. 65 of the American Railway Engineering and Maintenance of Way Association, the distillate based on water free oil shall be within the following limits:

At 210 degrees centigrade, not more than 5 per centum.
At 235 degrees centigrade, not more than 35 per centum.
At 315 degrees centigrade, not more than 85 per centum.

The oil shall yield a coke residue not exceeding three (3) per centum.

The distillate, between 210 degrees centigrade and 235 degrees centigrade, shall yield solids on cooling to 15 degrees centigrade. The preservative shall contain not more than 3 per centum of water.

59.5. The manufacturer of the oil shall permit full and complete inspection and sampling at the factory at which the oil is produced,

of all materials either crude or refined, entering into the manufacture of the finished product itself, in order that the materials used can be determined to be in accordance with the foregoing requirements. He shall also submit satisfactory proof of the origin of all materials entering into the composition of the finished product.

Samples of the preservative taken by the inspector from the treating tank during the progress of the work shall at no time show an accumulation of more than 2 per centum of foreign matter, such as sawdust or dirt.

59.6. The blocks shall be treated with the preservative above described, so that they shall contain at least sixteen pounds of the same per cubic foot of timber.

The manufacturer of the block shall equip his plant with all necessary gauges, appliances and facilities to enable the inspector to satisfy himself that the requirements of the specifications are fulfilled.

59.7. Upon the foundation shall be spread a bed of cement mortar at no place less than one-half inch in thickness, composed of one part Portland cement and four parts sand thoroughly mixed dry. This mortar bed shall be struck with a template to a true surface exactly parallel to the top of the proposed pavement surface and three inches below it. This bed shall be sprinkled, immediately in advance of the block laying, with hand sprinklers.

59.8. On the mortar surface prepared as described, the blocks shall be laid with grain vertical and at such angles with the curb as the Engineer may direct. The blocks shall be laid in straight and parallel courses and set snugly together but not driven together. Each course of blocks shall be of uniform width and depth, with end joints broken by a lap of not less than two and one-half inches. Only whole blocks shall be used except in starting courses, cutting closures, or where specially permitted by the Engineer.

Closures shall be carefully cut and trimmed by experienced men, the portion of the blocks used shall be free from defects and the cut end shall have a surface perpendicular to the top of the block and cut at a proper angle to give a close joint. In laying block the pavers must stand on the block previously laid.

After the laying is completed, defective blocks shall be carefully culled out, low blocks raised, the courses carefully aligned and the blocks spaced up. The pavement shall then be rolled by a steam tandem roller weighing not less than two and one-half tons nor more than five tons; the pavement being at the same time lightly sprinkled and the rolling continued until a uniform surface is obtained. Upon the completion of the rolling any defective blocks shall be removed and be replaced with sound blocks, and displaced blocks shall be re-aligned. The joints in the pavement shall then be immediately filled in the manner hereinafter described. If deemed advisable by the Engineer, portions of pavement laid with blocks which have become "dried out" shall be sprinkled with water at frequent intervals before joints of same are filled.

59.9. After rolling, the blocks shall be flushed with an approved bituminous filler heated to at least 300 degrees Fahrenheit, which shall be poured over the whole surface and well forced into the joints

by rubber squeegees. While the bituminous filler is still hot it shall be immediately followed with a thin coating of clean dry sand. Before turning traffic onto the pavement a coating of one-half inch in thickness of dry screened sand shall be spread over the entire surface.

59.10. The quantity to be paid for under this item shall be the number of square yards, including expansion joints, of pavement laid in accordance with the plans and as directed by the Engineer.

The price bid shall include the furnishing and placing of the mortar bed, wood block, bituminous filler and sand surfacing and all other labor and incidental expenses necessary to complete the work.

Item 60 — Asphalt Block Pavement

60.1. Under this item the Contractor shall furnish and place upon a properly prepared foundation asphalt block of the quality specified where shown upon the plans or ordered by the Engineer. This pavement shall be placed upon the old macadam, old concrete pavement, new concrete foundation or on other foundations as ordered by the Engineer and shown upon the plans.

60.2. The blocks shall be five inches in width, by twelve inches in length, by two inches in depth, and a variation of more than one-fourth of an inch in length and one-eighth of an inch in width or depth from these dimensions will be sufficient ground for rejecting any block.

60.3. The blocks shall consist of the following materials:

Asphaltic cement.

Crushed trap rock or other approved crushed rock.

Inorganic dust.

The rock used in the blocks must be crushed so that every particle will pass a screen of one-fourth of an inch mesh. The blocks shall receive a compression in the moulds of not less than one ton per cubic inch of material in the blocks, and must weigh not less than ten and one-half pounds per block. The blocks shall have a specific gravity of not less than 2.40, and after having been dried for twenty-four hours at a temperature of 150 degrees Fahrenheit, they shall not absorb more than one per centum of moisture when immersed in water for seven days. Whatever the character of the asphalt used, the block shall yield not less than six and one-half per centum of bitumen, when extracted with carbon bisulphide.

The inorganic dust, or filler, shall be produced from sound limestone or other approved material, and shall be powdered to such a fineness that all of it shall pass a thirty mesh sieve and not less than fifty per centum of it shall pass a 200 mesh sieve. Sufficient inorganic dust shall be used to give a minimum percentage of voids in the block, and provide a sufficient medium for absorbing the asphaltic cement.

60.4. The asphaltic cement shall be composed of natural or oil asphalt, and asphaltic oil, as approved. This asphaltic cement shall be of acceptable consistency and quality.

The material shall have a specific gravity of at least 0.98 at 77 degrees Fahrenheit. Its penetration shall be not more than ten mm. when tested for five seconds at 77 degrees Fahrenheit, with a No. 2 needle weighted with 100 grams. When twenty grams are heated in a hot air oven in a flat-bottom dish two and one-half inches in diameter at 325 degrees Fahrenheit for five hours, the loss in weight shall not be more than eight per centum. It shall show an open flash point not less than 325 degrees Fahrenheit. Its solubility at air temperature in chemically pure carbon disulphide shall be at least sixty-six per centum.

60.5. Upon the foundation shall be spread a bed of the thickness shown upon the plans, composed of one part Portland cement and four parts sand, thoroughly mixed.

This mortar bed shall be struck with a template to a true surface, exactly parallel to the top of the proposed pavement surface and two inches below it.

This bed shall be sprinkled immediately in advance of the block laying with hand sprinklers.

The blocks shall be laid while the mortar is fresh and before it has taken its initial set. All depressions and other irregularities in the surface shall be corrected by the Contractor immediately.

The blocks shall be laid by the pavers standing upon the blocks already laid and not upon the bed of mortar.

The blocks shall be laid at right angles with the line of the street, and in such a manner that all longitudinal joints shall be broken by a lap of at least four inches. The blocks shall be so laid as to make the lateral joints as tight as possible, consistent with keeping a good alignment of the courses across the street. When thus laid the blocks shall be immediately covered with clean, fine sand, perfectly dry, and screened through a one-eighth inch screen. This sand shall be spread over the surface and swept into the joints and be allowed to remain on the pavement not less than thirty days or for such time as the action of the traffic on the street shall have thoroughly ground the sand into all the joints.

60.6. The materials incorporated into blocks shall be approved by the Engineer, and samples of all materials shall be sent to the Bureau of Tests and they shall pass the tests required by this Bureau for these materials.

60.7. The methods of work and materials used shall at all times be subject to the inspection and supervision of the Engineer or his representative upon the work.

60.8. The quantity to be paid for under this item shall be the number of square yards of asphalt block laid in accordance with the plans or as directed by the Engineer. The price bid shall include the furnishing and placing of all materials, mortar bed, and all labor and incidental expenses necessary to complete the work. Where placed upon old concrete foundation or upon old macadam the preparation of the foundation to receive the mortar bed will be paid for under item "CLEANING OLD PAVEMENT" or item "SCARIFYING AND RESHAPING OLD MACADAM."

Item 61 — Brick Pavement

61.1. Under this item the Contractor shall furnish and place the number of square yards of brick pavement required in accordance with the plans or as ordered by the Engineer. The item will include the furnishing and placing of all the block, sand cushion, grout, expansion joints and all material, labor and other expenses incidental thereto but will not include the concrete foundation, edging, curbing, manholes, catch basins, etc., which will be paid for under the especially designated items therefor.

61.2. All bricks or blocks used must be vitrified and especially burned for street paving and of the very best quality as regards hardness, dimensions, toughness, straight lines and non-absorption of water.

61.3. The paving bricks shall be subjected to modulus of rupture test and to abrasion tests conducted by the Commission in the manner and with rattlers of the type adopted February 7, 1911, by the National Paving Brick Manufacturers Association. One sample shall be tested for every two hundred thousand (200,000) bricks and less than this when conditions warrant. An average loss in weight in a rattler test exceeding twenty-four (24) per centum, or an average absorption of three and one-half ($3\frac{1}{2}$) per centum of water shall cause the rejection of the total quantity that the test represents, provided, however, that if permitted the bricks may be carefully reculled, and new samples taken and tested. If this second test passes the requirements, the bricks represented by it may be used. If this second test fails, no further test shall be permitted but the entire lot shall be rejected. To ensure the furnishing of bricks of uniformly acceptable quality, any "brand" of brick shall be rejected and shall not be further considered if three lots, each of ten thousand (10,000) bricks or more, offered consecutively for acceptance tests, fail to meet the requirements for this section without reculling them.

Modulus of Rupture. When tested on edge as laid on the pavement, the modulus of rupture shall be not less than two thousand (2,000) pounds per square inch. Computed by formula $R = 3\frac{WL}{2bd^2}$, in which R is the modulus of rupture in pounds per square inch, L the length between supports in inches (= 6 inches), b and d the breadth and depth in inches, and W the load in pounds, which produces rupture.

All the above tests will be made by the Bureau of Tests of the State Commission of Highways.

61.4. On grades of 5 per centum or over an approved special form of block suitable for steep grades shall be used.

61.5. The size of the brick shall be $3\frac{1}{2}$ inches in width by four inches in depth by $8\frac{1}{2}$ inches in length, and shall not vary from these dimensions more than one-eighth inch in width or depth nor more than one-half inch in length. Bricks of a given brand shall not vary among themselves more than $\frac{1}{4}$-inch in depth nor more than $\frac{1}{8}$-inch in width nor more than $\frac{1}{2}$-inch in length in any one shipment. If the edges

are rounded the radius shall not be greater than $\frac{3}{16}$ of an inch. One side shall contain lugs of such dimensions that transverse joints will not be less than $\frac{3}{16}$ of an inch nor more than $\frac{1}{4}$-inch in width. Each end shall contain a semi-circular groove of $\frac{1}{8}$ to $\frac{1}{4}$-inch radius, or a bulge or at least $\frac{1}{16}$ inch. The grooves shall be horizontal, and shall match perfectly when the bricks are laid in the finished pavement. Bricks in any course shall not vary in width by more than $\frac{1}{8}$-inch.

61.6. Not less than ten days after the concrete foundation has been completed, there shall be laid a bed of clean Cushion Sand as described under "Materials of Construction," which shall be one and one-half inches thick after being rolled with a roller weighing 150 pounds per foot of width. Before being rolled this bed of sand shall be brought to the proper elevation and crown as shown on plans by a template of a shape and size satisfactory to the Engineer. After being rolled all irregularities of the surface shall be eliminated and the sand cushion shall be brought to the exact form and section by the use of lutes or hand templates.

61.7. Longitudinal expansion joints shall be placed alongside each curb or edging, and shall be one of the following types:

Premolded Type, requiring no heating or pouring at the place of insertion. These expansion joints shall be of the proper thickness and width, as specified, made in convenient lengths ready for use. The joints shall be placed as the paving progresses, and shall rest directly on the sand cushion. The expansion joints shall be composed *entirely* of a high grade asphalt, and shall pass the following tests:

Specific gravity	.985	to	1.002
Melting point	235°	to	265° F.
Loss on heating for 5 hours at 325° F.	.0%		
Bitumen soluble in carbon disulphide	99.5%	to	99.9%
Bitumen soluble in carbon tetra-chloride	99.4%	to	99.8%
Bitumen soluble in Be. Naphtha		to	%
Penetration at 32° F.	25	to	35
Penetration at 77° F.	40	to	50
Penetration at 115° F.	65	to	75

Poured Type. This type shall be provided for by placing alongside each curb or edging wooden strips with metal wedge shape pieces dropped over the top of the boards and between the board and the curb every three feet apart to facilitate the removal of the boards, or, by using two planed wedge-shaped strips so cut that when placed together in reverse positions their total section shall be rectangular and of a thickness and depth equal to the thickness and depth of the required expansion joint. The strip placed next to the curb shall be set with the wide edge up. These expansion joint forms shall be set next to the curb on a true grade with all end joints tight, and be pressed into sand so that their tops shall be one-quarter inch below the top surface of the pavement blocks before rolling. The two strips comprising the joint form shall break joints.

The thickness of longitudinal expansion joints shall be as called for by the plan.

61.8. On the sand cushion prepared as in section 61.6 the blocks shall be carefully set on edge with the best edge up, shall be laid straight at and right angles to the edging line, except at road intersections, where they shall be laid at such angles as directed by the Engineer. All block shall be laid with the lugs in the same direction, joints shall be close and at right angles to the tops and sides. Each alternate course shall be commenced with a half brick. No half bricks or bats shall be used except at the ends of courses. All joints shall be broken with a lap of not less than three (3) inches.

All brick shall be clean when placed in the pavement. Brick which in the opinion of the Engineer are not satisfactorily clean, shall be washed before being placed.

In no case shall the sand cushion in front of the pavement be disturbed or walked on during the laying of the blocks.

61.9. After a sufficient number of blocks have been laid, all soft, broken or badly misshapen blocks shall be marked by the inspector and removed. Any blocks slightly spalled or kiln-marked shall be turned over, and should the opposite face be acceptable, it may be replaced in the pavement, otherwise, it must be removed.

In laying block pavement, the inspector shall keep the blocks culled, and the Contractor shall make the necessary changes and replacements so that the work shall at all times be ready for grouting within 300 feet from the block-laying.

61.10. After all objectionable blocks have been removed from the pavement and all replacements have been made, the pavement shall be swept clean and thoroughly rolled with a self-propelled tandem roller weighing not over five tons and not less than three tons. Horse rolling shall not be permitted. This rolling shall start along the outside edges and progress toward the center. It shall then be rerolled diagonally both ways until the surface is even. After final rolling the pavement shall be tested with a ten-foot straight edge laid parallel with the curb, and any depression exceeding one-quarter inch shall be corrected and brought to the proper grade. All blocks disturbed in making replacements or correcting depressions shall be settled into place by ramming or by rerolling. Each section of pavement must be acceptable to the Engineer before the grouting on that section may be commenced.

61.11. Grout for filling the joints of brick or block pavements shall be composed of one part Portland cement and one part Grout Sand.

61.12. The box for mixing this grout shall be about four feet eight inches long, two feet six inches wide and one foot two inches deep, supported on legs of different lengths in order that the mixture shall readily flow to the lowest corner, which shall not be more than six inches above the pavement. Approved mechanical grout mixers may be used.

61.13. The mixture, not exceeding one sack of cement together with a like amount of sand, shall be placed in the box and mixed dry, until the mass assumes a uniform color. Water shall then be added, forming a liquid mixture of the consistency of thin cream for the first coat and slightly thicker for each succeeding coat. From

the time the water is applied until the last drop is removed and floated into the joints of the pavement the mixture must be constantly agitated.

61.14. The brick shall be wet to the satisfaction of the Engineer before any grout is placed. The grout shall be removed from the box to the street surface with a scoop shovel and immediately swept into the joints, the mixture in the box being constantly agitated while this is being done.

The work of grouting shall proceed for the entire width of the pavement. When sufficient time has elapsed for the grout to thoroughly penetrate all the joints, but before the cement has attained its initial set, the section treated shall be gone over a second time in the same manner, care being taken to thoroughly fill all joints from the bottom flush with the top of the block. If necessary to secure flush joints, a third, fourth or fifth coat of the grout shall be swept in and smoothed off with a suitable squeegee.

Care shall be taken to so conduct the grouting that no part of any joint will receive an application of the second grout until the first is satisfactorily completed, nor of the third until the second is completed, etc. To insure this result metal strips 1–16 in. by 6 in. by 3 ft. must be inserted, for the full length of the joint, at work intervals; all of the several applications of grout must be completed up to this joint before any grouting is begun on the other side of it.

61.15. After the joints are thus filled flush with the top of the blocks and sufficient time for hardening has taken place, so that the cover coat will not absorb any moisture from the grout, one inch of suitable material shall be spread evenly over the entire surface, and be kept moist for a period of at least ten days and until the grout has thoroughly set.

During this period the section grouted must remain absolutely free from disturbance or traffic of any kind. After 30 days from the spreading, this cover coat shall be completely removed.

61.16. In case the poured type of expansion joint is used, after the grout has set but within thirty-six hours after its application the expansion joint forms shall be withdrawn and the space thus formed thoroughly cleaned and a bituminous filler having a melting point not less than 120 degrees Fahrenheit nor more than 140 degrees Fahrenheit shall be immediately poured into place at a temperature not less than 200 degrees Fahrenheit.

61.17. If required, transverse expansion joints shall be constructed of the materials and in the manner prescribed by the Engineer.

61.18. The quantity of pavement to be paid for under this item shall be the number of square yards placed in accordance with the plans or directions of the Engineer. The price bid per square yard shall include the sand cushion, paving block, grout, material for expansion joint, sand covering, sprinkling, and all other labor, materials and incidentals necessary to satisfactorily complete the work.

The amount to be estimated under this item shall be computed by multiplying the actual width of pavement, including expansion joints, by the total length of pavement measured along the axis of the road and parallel to the surface.

Item 62 — Stone Block Pavement

62.1. Under this item the Contractor shall furnish and place upon a properly prepared foundation Stone Block pavement of the quality specified below, where shown upon the plans or directed by the Engineer.

The item will include the furnishing and placing of all the block, sand cushion, grout, expansion joints and all material, labor and other expenses incidental thereto but will not include the concrete foundation, edging, curbing, manholes, catch basins, etc., which will be paid for under the especially designated items therefor.

62.2. The dimensions of the blocks shall be as follows: Not less than six inches nor more than twelve inches long on top, not less than three and one-half inches nor more than four and one-half inches wide on top, and not less than four inches nor more than five inches deep. They shall be dressed so that after laying, no measurement of any joint shall show a width of more than one-half inch for a depth of one inch, or a width of more than one inch in any part of the joint. The head of the block shall be so cut that it shall not have a depression in it more than three-eighths inch deep, and the edges and corners must be full unchipped and unbroken. All blocks shall be sorted and laid in straight courses of uniform width and depth.

62.3. The blocks shall be of stone of medium sized grain showing an even distribution of constituent material. They shall be of uniform quality and texture, without seams, scales or disintegration, and free from an excess of mica or feldspar. They shall be made from rock which when tested in the Deval Rattler will show a "coefficient of wear" of more than 7 and less than 14. All blocks for any one contract shall be from the same quarry unless otherwise directed.

62.4. On the prepared foundation, sufficient clean Cushion Sand as described under "Materials of Construction" on page 375, shall be spread to such a thickness that after the pavement has been thoroughly rammed or settled the sand under the block shall be nowhere less than one inch thick.

On the sand cushion above specified, the blocks shall be set vertically on edge in close contact with each other, and in straight rows across the road at right angles to the curb, except at intersections, where the angle of the rows with the curb shall be varied to meet the conditions. Blocks in adjoining rows shall be set to break joints not less than three inches. All blocks shall be set so that when thoroughly rammed or settled to a firm, unyielding bearing, they will then be true to lines, grades and cross sections, and have no joints greater than the maximum allowable. All depressions or irregularities in the surface shall be corrected to the satisfaction of the Engineer. Only practiced and competent pavers shall be employed in laying the blocks.

After the blocks are laid, sufficient approved clean gravel shall be spread over the surface and swept into the joints so as to fill the latter to a depth of about two inches from the bottom. The blocks shall

then be thoroughly rammed or rolled until firm, even and true to the lines, grades and cross sections.

Approved expansion joints shall be provided along the curb as may be required and shall be filled with the same quality of filler as is specified for expansion joints in brick pavements. Portland cement grout mixed in proportions of one part cement and one part sand shall then be poured into the joints until the grout flushes to the surface of the pavement. The grout shall be broomed when required, and the pouring and brooming shall be continued until all the joints are thoroughly filled, and the grout is even with the highest part of any and all blocks. Sprinkling or otherwise wetting the blocks before grouting shall be done when atmospheric or other conditions require this precaution to be taken.

62.5. After grouting shall have been completed and the grout shall have sufficiently hardened, a coating of suitable material about one inch deep shall be spread over the whole surface of the grouted pavement, and the road shall then be sprinkled with water. This covering shall be kept wet, and no travel of any kind shall be allowed on the completed pavement for at least seven days thereafter, nor until the grout shall have thoroughly set, when the covering shall be completely removed.

62.6. The quantity to be paid for under this item shall be the number of square yards, including expansion joints, of pavement laid in accordance with the plans and as directed by the Engineer.

The price bid shall include the furnishing and placing of all materials, the spreading of sand cushion, the laying, ramming or rolling, grouting, surfacing and all labor and incidental expenses necessary to complete the work.

MEDINA SANDSTONE BLOCK PAVEMENT

(City of Rochester, N.Y., Specifications, 1911)

The grading, subwork, and curbs having been completed as herein specified under the proper headings, the work of laying the concrete foundation and paving will then proceed.

A concrete foundation six (6) inches thick, of Portland cement, as specified in the bidding sheet and shown in plans, will be laid in accordance with the specifications herein contained. The surface will be eight (8) inches below the finished pavement and parallel thereto, or seven (7) inches if a five (5) inch block is specified.

The surface to be kept wet until covered with sand, and, at least, thirty-six (36) hours shall be allowed for the concrete to set before the pavement is laid. When connection is to be made with any layer set, or partially set, the edge of such layer must be broken down, shall be free from dust and properly wet, so as to make the joints fresh and close. On this concrete foundation shall be laid a bed of clean, sharp sand, perfectly free from moisture (made so by artificial heat if deemed necessary), not less than one (1) inch thick, to the depth necessary to bring the pavement and crosswalks to the proper grade when thoroughly rammed.

Upon this bed of sand, the stone blocks and crosswalks must be laid. The stone blocks are to be laid in straight courses at right angles with the line of the street, except in intersections of streets, where the courses shall be laid diagonally, and except in special cases, when they shall be laid at such angle, with such crown and at such grade as the city engineer may direct. Each course of blocks shall be uniform in width and depth, and shall be gauged and selected for the pavers on the sidewalks, and so laid that *all longitudinal joints or end joints shall be close joints and shall be broken by a lap of at least three inches*, and that joints between courses shall not be more than one-half inch in width. The blocks shall then be thoroughly rammed by courses at least three times by a rammer weighing not less than eighty (80) pounds — no iron of any kind being allowed on its lower face to come in contact with the paving, and until brought to an unyielding bearing, with a uniform surface, true to the roadway on the established grade. The surface of the pavement thus completed must be even and smooth throughout and molded to conform to the wells of the surface sewers, street and alley intersections, drainage details, and the grade lines established by the city engineer. During the final ramming the pavement shall be tested with a straight-edge and templet, and any unevenness must be taken out and made true to the required grade, level, and cross-section.

If a paving pitch filler is used, the joints shall be filled with clean, dry, hot gravel of proper size as herein specified, heated in pans especially provided for that purpose, and poured from cans having small spouts and thoroughly settled in place with wire picks until the level of the gravel is at least two inches below the top of the pavement.

The gravel used between the blocks shall be of such size as will pass through a sieve having four meshes per square inch, and be retained on a sieve of sixty-four meshes per square inch, and must be screened when dry.

There shall be immediately poured into the joints, while the gravel is hot, boiling paving cement as hereinafter described, heated to a temperature of 300° F. until the joints and all interstices of gravel filling are full and will take no more, and are filled flush with the top of the blocks. Dry, hot gravel must then be poured along the joints, filled with paving cement, as above described.

The paving cement to be used in filling the joints as herein provided shall be a paving pitch of the best quality, of a brand that has been proved by actual use in pavements known to the city engineer to be best adapted to the purpose. It shall be delivered on the work in lots at least one week before using, in order that the necessary analysis and examination may be made by the city engineer. In addition to this the contractor must furnish the city engineer with the certificate of the manufacturer or refiner that the materials are of the kind specified.

The city engineer may direct that a Portland cement grout filler may be used in the joints instead of a paving pitch, in which case the pavement shall be thoroughly sprinkled or washed with water before grouting. The grout shall be mixed with clean, sharp sand

of approved quality, in the proportion of one to one, the cement and sand to be thoroughly mixed together dry, in a box, and then only a sufficient amount of water added to make the grout of the proper fluidity when thoroughly stirred.

The grout shall be prepared only in small quantities at a time, and shall be stirred rapidly and constantly in the box and while being applied to the pavement, and no settlings or residue will be allowed to be used.

The grout shall be transferred to the pavement in such a way as the engineer may think most advantageous and best for the work, and shall then be rapidly swept into the joints of the pavement with proper brooms. The stones shall be well wet as directed before the grout is applied, and the pouring must be continued until the joints remain full.

All teams and traffic of any kind, except on planks, shall be rigidly prohibited on the pavement for ten days after the grout is applied, or until, in the opinion of the engineer, it has become thoroughly set and hardened, so that the bond will not be broken by traffic over the pavement.

Conversion Table 55

Linear Units

Old Surveyors' Units

1 link = 7.92 in.
100 links = 1 chain = 66 ft.
25 links = 1 rod = 16.5 ft.

Ordinary Measure

12 in. = 1 ft.
3 ft. = 1 yd.
5280 ft. = 1 mile

Square Units

1 sq. ft.	=	144 sq. in.
1 sq. yd.	=	9 sq. ft.
	=	1296 sq. in.
1 acre	=	43,560 sq. ft.
	=	4840 sq. yds.
1 sq. mile	=	27,878,400 sq. ft.
	=	3,097,600 sq. yds.
	=	640 acres

Volume Units

1 cu. ft.	=	1728 cu. in.
	=	7.4805 ordinary gal.
	=	6.232 Imperial gal.
1 cu. yd.	=	27 cu. ft.
	=	46,656 cu. in.
1 ordinary gal.	=	231 cu. in.
1 Imperial gal.	=	277 cu. in.
1 barrel	=	31.5 gal.
	=	4.21 cu. ft.

Weight Units

1 pound	=	16 ounces
1 ordinary ton	=	2000 pounds
1 long ton	=	2240 pounds

Temperature Units

Freezing point of water	=	32° Fahrenheit
	=	0° Centigrade
Boiling point of water at normal air pressure	=	212° Fahrenheit
	=	100° Centigrade
1 degree Fahrenheit	=	0.5556 degree Centigrade
1 degree Centigrade	=	1.8 degrees Fahrenheit

TABLE 56

EQUIVALENTS OF INCHES AND FRACTIONS OF INCHES IN DECIMALS OF A FOOT

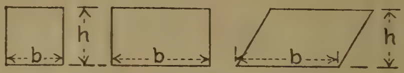
In.	0 In.	1 In.	2 In.	3 In.	4 In.	5 In.
		.0833	.1667	.2500	.3333	.4167
1/32	.0026	.0859	.1693	.2526	.3359	.4193
1/16	.0052	.0885	.1719	.2552	.3385	.4219
3/32	.0078	.0911	.1745	.2578	.3411	.4245
1/8	.0104	.0938	.1771	.2604	.3438	.4271
5/32	.0130	.0964	.1797	.2630	.3464	.4297
3/16	.0156	.0990	.1823	.2656	.3490	.4323
7/32	.0182	.1016	.1849	.2682	.3516	.4349
1/4	.0208	.1042	.1875	.2708	.3542	.4375
9/32	.0234	.1068	.1901	.2734	.3568	.4401
5/16	.0260	.1094	.1927	.2760	.3594	.4427
11/32	.0286	.1120	.1953	.2786	.3620	.4453
3/8	.0313	.1146	.1979	.2813	.3646	.4479
13/32	.0339	.1172	.2005	.2839	.3672	.4505
7/16	.0365	.1198	.2031	.2865	.3698	.4531
15/32	.0391	.1224	.2057	.2891	.3724	.4557
1/2	.0417	.1253	.2083	.2917	.3750	.4583
17/32	.0443	.1276	.2091	.2943	.3776	.4609
9/16	.0469	.1302	.2135	.2969	.3802	.4635
19/32	.0495	.1328	.2161	.2995	.3828	.4661
5/8	.0521	.1354	.2188	.3021	.3854	.4688
21/32	.0547	.1380	.2214	.3047	.3880	.4714
11/16	.0573	.1406	.2240	.3073	.3906	.4740
23/32	.0599	.1432	.2266	.3099	.3932	.4766
3/4	.0625	.1458	.2292	.3125	.3958	.4792
25/32	.0651	.1484	.2318	.3151	.3984	.4818
13/16	.0677	.1510	.2344	.3177	.4010	.4844
27/32	.0703	.1536	.2370	.3203	.4036	.4870
7/8	.0729	.1563	.2396	.3229	.4063	.4896
29/32	.0755	.1589	.2422	.3255	.4089	.4922
15/16	.0781	.1615	.2448	.3281	.4115	.4948
31/32	.0807	.1641	.2474	.3307	.4141	.4974

Equivalents of Inches and Fractions of Inches in Decimals of a Foot

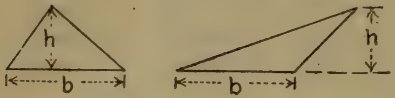
In.	6 In.	7 In.	8 In.	9 In.	10 In.	11 In.
	.5000	.5833	.6667	.7500	.8333	.9167
$\frac{1}{32}$	.5026	.5859	.6693	.7526	.8359	.9193
$\frac{1}{16}$	.5052	.5885	.6719	.7552	.8385	.9219
$\frac{3}{32}$	.5078	.5911	.6745	.7578	.8411	.9245
$\frac{1}{8}$	.5104	.5938	.6771	.7604	.8438	.9271
$\frac{5}{32}$	.5130	.5964	.6797	.7630	.8464	.9297
$\frac{3}{16}$	.5156	.5990	.6823	.7656	.8490	.9323
$\frac{7}{32}$	.5182	.6016	.6849	.7682	.8516	.9349
$\frac{1}{4}$	.5208	.6042	.6875	.7708	.8542	.9375
$\frac{9}{32}$	.5234	.6068	.6901	.7734	.8568	.9401
$\frac{5}{16}$	.5260	.6094	.6927	.7760	.8594	.9427
$\frac{11}{32}$	.5286	.6120	.6953	.7786	.8620	.9453
$\frac{3}{8}$	.5313	.6146	.6979	.7813	.8646	.9479
$\frac{13}{32}$	.5339	.6172	.7005	.7839	.8672	.9505
$\frac{7}{16}$	.5365	.6198	.7031	.7865	.8698	.9531
$\frac{15}{32}$	.5391	.6224	.7057	.7891	.8724	.9557
$\frac{1}{2}$	.5417	.6250	.7083	.7917	.8750	.9583
$\frac{17}{32}$	.5443	.6276	.7109	.7943	.8776	.9609
$\frac{9}{16}$	.5469	.6302	.7135	.7969	.8802	.9635
$\frac{19}{32}$	.5495	.6328	.7161	.7995	.8828	.9661
$\frac{5}{8}$	.5521	.6354	.7188	.8021	.8854	.9688
$\frac{21}{32}$	.5547	.6380	.7214	.8047	.8880	.9714
$\frac{11}{16}$	.5573	.6406	.7240	.8073	.8906	.9740
$\frac{23}{32}$	.5599	.6432	.7266	.8099	.8932	.9766
$\frac{3}{4}$	.5625	.6458	.7292	.8125	.8958	.9792
$\frac{25}{32}$	.5651	.6484	.7318	.8151	.8984	.9818
$\frac{13}{16}$	.5677	.6510	.7344	.8177	.9010	.9844
$\frac{27}{32}$	.5703	.6536	.7370	.8203	.9036	.9870
$\frac{7}{8}$	.5729	.6563	.7396	.8229	.9063	.9896
$\frac{29}{32}$	.5755	.6589	.7422	.8255	.9089	.9922
$\frac{15}{16}$	.5781	.6615	.7448	.8281	.9115	.9948
$\frac{31}{32}$	.5807	.6641	.7474	.8307	.9141	.9974

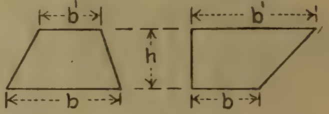
Table 57. Areas and Volumes

Areas

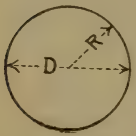


Squares, Rectangles, and Parallelograms. Area $= bh$





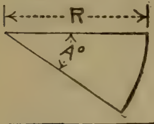
Triangles Area $= \frac{1}{2}\, bh$ *Trapezoids* Area $= \dfrac{b + b'}{2} h$



Circles

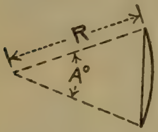
$$\text{Area} = \pi R^2 = \frac{\pi D^2}{4}$$

Circumference of Circle $= 2\, \pi R = \pi D$
Commonly used value of $\pi = 3.1416$



Sector of Circle

$$\text{Area} = \pi R^2 \frac{A^\circ}{360^\circ}$$



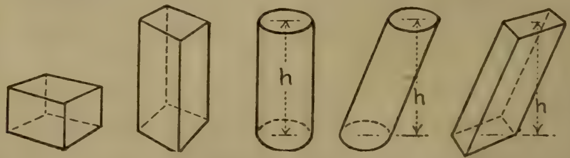
Segment of a Circle

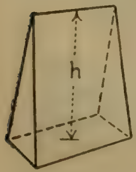
$$\text{Area} = \left(\pi R^2 \frac{A^\circ}{360^\circ} \right) - \left(\left(R \sin \frac{A}{2}\right) \cdot \left(R \cos \frac{A}{2}\right) \right)$$

Volumes

Cubes, Rectangular Prisms, Parallelopipeds, Cylinders, etc. All solids having parallel bases and a constant cross-section.

Volume = area of base × perpendicular height between the planes of the bases.



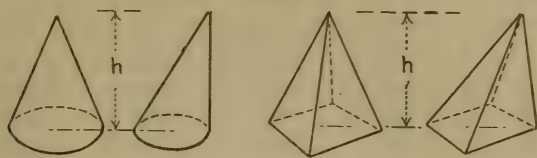


Wedges. Having parallel ends.

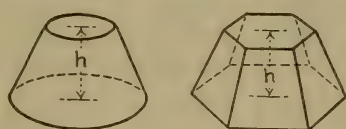
Volume = area of base × $\frac{1}{2}$ the height perpendicular to the plane of the base.

Cones and Pyramids, whether right or oblique, regular or irregular.

Volume = $\frac{1}{3}$ area of the base × height perpendicular to the plane of the base



Frustums of Pyramids or Cones, whether right or oblique, regular or irregular provided the base and top are parallel.



$$\text{Volume} = \tfrac{1}{3}\ \begin{matrix}\text{perpendicular}\\ \text{height between base and top}\end{matrix} \times \left(\begin{matrix}\text{area}\\ \text{top}\end{matrix} + \begin{matrix}\text{area}\\ \text{base}\end{matrix} + \sqrt{\begin{matrix}\text{area}\\ \text{top}\end{matrix} \times \begin{matrix}\text{area}\\ \text{base}\end{matrix}}\right)$$

or by the prismoidal formula

$$\begin{matrix}\text{Volume}\\ = \tfrac{1}{6}\ \text{perpendicular height}\\ \text{between base and top}\end{matrix} \times \left(\begin{matrix}\text{area}\\ \text{top}\end{matrix} + \begin{matrix}\text{area}\\ \text{base}\end{matrix} + \begin{matrix}4 \times \text{area of section par-}\\ \text{allel to and midway}\\ \text{between base and top}\end{matrix}\right)$$

Prismoidal Formula

Trautwine defines a prismoid as a solid having for its ends two parallel plane figures connected by other plane figures on which and through every point of which a straight line may be drawn from one of the two parallel ends to the other. These connecting planes may be parallelograms or not and parallel to each other or not. This includes cubes, all parallelopipeds, prisms, cylinders, pyramids, cones, and their frustums, provided the top and base are parallel and wedges.

The prismoidal formula applies to all these solids either alone or to any form that can be separated into units of the above forms.

Prismoidal formulæ

$$\text{Volume} = h \times \frac{A + a + 4M}{6}$$

h = perpendicular distance between the parallel ends
A = area of one of the parallel ends
a = area of the other parallel end
M = area of a cross-section midway between and parallel to the two parallel ends

Sphere

$$\text{Volume} = \tfrac{4}{3}\pi R^3 = 4.1888\ R^3$$
$$= \tfrac{1}{6}\pi D^3 = 0.5236\ D^3$$

In which R = radius of sphere
D = diameter of sphere

Table 58

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Circular Areas of Nos. from 1 to 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
1	1	1	1.0000	1.0000	3.142	0.7854
2	4	8	1.4142	1.2599	6.283	3.1416
3	9	27	1.7321	1.4422	9.425	7.0686
4	16	64	2.0000	1.5874	12.566	12.5664
5	25	125	2.2361	1.7100	15.708	19.6350
6	36	216	2.4495	1.8171	18.850	28.2743
7	49	343	2.6458	1.9129	21.991	38.4845
8	64	512	2.8284	2.0000	25.133	50.2655
9	81	729	3.0000	2.0801	28.274	63.6173
10	100	1000	3.1623	2.1544	31.416	78.5398
11	121	1331	3.3166	2.2240	34.558	95.033
12	144	1728	3.4641	2.2894	37.699	113.097
13	169	2197	3.6056	2.3513	40.841	132.732
14	196	2744	3.7417	2.4101	43.982	153.938
15	225	3375	3.8730	2.4662	47.124	176.715
16	256	4096	4.0000	2.5198	50.265	201.062
17	289	4913	4.1231	2.5713	53.407	226.980
18	324	5832	4.2426	2.6207	56.549	254.469
19	361	6859	4.3589	2.6684	59.690	283.529
20	400	8000	4.4721	2.7144	62.832	314.159
21	441	9261	4.5826	2.7589	65.973	346.361
22	484	10648	4.6904	2.8020	69.115	380.133
23	529	12167	4.7958	2.8439	72.257	415.476
24	576	13824	4.8990	2.8845	75.398	452.389
25	625	15625	5.0000	2.9240	78.540	490.874
26	676	17576	5.0990	2.9625	81.681	530.929
27	729	19683	5.1962	3.0000	84.823	572.555
28	784	21952	5.2915	3.0366	87.965	615.752
29	841	24389	5.3852	3.0723	91.106	660.520
30	900	27000	5.4772	3.1072	94.248	706.858
31	961	29791	5.5678	3.1414	90.389	754.768
32	1024	32768	5.6569	3.1748	100.531	804.248
33	1089	35937	5.7446	3.2075	103.673	855.299
34	1156	39304	5.8310	3.2396	106.814	907.920
35	1225	42875	5.9161	3.2711	109.956	962.113
36	1296	46656	6.0000	3.3019	113.097	1017.88
37	1369	50653	6.0828	3.3322	116.239	1075.21
38	1444	54872	6.1644	3.3620	119.381	1134.11
39	1521	59319	6.2450	3.3912	122.522	1194.59
40	1600	64000	6.3246	3.4200	125.660	1256.64

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
41	1681	68921	6.4031	3.4482	128.81	1320.25
42	1764	74088	6.4807	3.4760	131.95	1385.44
43	1849	79507	6.5574	3.5034	135.09	1452.20
44	1936	85184	6.6332	3.5303	138.23	1520.53
45	2025	91125	6.7082	3.5569	141.37	1590.43
46	2116	97336	6.7823	3.5830	144.51	1661.90
47	2209	103823	6.8557	3.6088	147.65	1734.94
48	2304	110592	6.9282	3.6342	150.80	1809.56
49	2401	117649	7.0000	3.6593	153.94	1885.74
50	2500	125000	7.0711	3.6840	157.08	1963.50
51	2601	132651	7.1414	3.7084	160.22	2042.82
52	2704	140608	7.2111	3.7325	163.36	2123.72
53	2809	148877	7.2801	3.7563	166.50	2206.18
54	2916	157464	7.3485	3.7798	169.65	2290.22
55	3025	166375	7.4162	3.8030	172.79	2375.83
56	3136	175616	7.4833	3.8259	175.93	2463.01
57	3249	185193	7.5498	3.8485	179.07	2551.76
58	3364	195112	7.6158	3.8709	182.21	2642.08
59	3481	205379	7.6811	3.8930	185.35	2733.97
60	3600	216000	7.7460	3.9149	188.50	2827.43
61	3721	226981	7.8102	3.9365	191.64	2922.47
62	3844	238328	7.8740	3.9579	194.78	3019.07
63	3969	250047	7.9373	3.9791	197.92	3117.25
64	4096	262144	8.0000	4.0000	201.06	3216.99
65	4225	274625	8.0623	4.0207	204.20	3318.31
66	4356	287496	8.1240	4.0412	207.35	3421.19
67	4489	300763	8.1854	4.0615	210.49	3525.65
68	4624	314432	8.2462	4.0817	213.63	3631.68
69	4761	328509	8.3066	4.1016	216.77	3739.28
70	4900	343000	8.3666	4.1213	219.91	3848.45
71	5041	357911	8.4261	4.1408	223.05	3959.19
72	5184	373248	8.4853	4.1602	226.19	4071.50
73	5329	389017	8.5440	4.1793	229.34	4185.39
74	5476	405224	8.6023	4.1983	232.48	4300.84
75	5625	421875	8.6603	4.2172	235.62	4417.86
76	5776	438976	8.7178	4.2358	238.76	4536.46
77	5929	456533	8.7750	4.2543	241.90	4656.63
78	6084	474552	8.8318	4.2727	245.04	4778.36
79	6241	493039	8.8882	4.2908	248.19	4901.67
80	6400	512000	8.9443	4.3089	251.33	5026.55

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
81	6561	531441	9.0000	4.3267	254.47	5153.00
82	6724	551368	9.0554	4.3445	257.61	5281.02
83	6889	571787	9.1104	4.3621	260.75	5410.61
84	7056	592704	9.1652	4.3795	263.89	5541.77
85	7225	614125	9.2195	4.3968	267.04	5674.50
86	7396	636056	9.2736	4.4140	270.18	5808.80
87	7569	658503	9.3274	4.4310	273.32	5944.68
88	7744	681472	9.3808	4.4480	276.46	6082.12
89	7921	704969	9.4340	4.4647	279.60	6221.14
90	8100	729000	9.4868	4.4814	282.74	6361.73
91	8281	753571	9.5394	4.4979	285.88	6503.88
92	8464	778688	9.5917	4.5144	289.03	6647.61
93	8649	804357	9.6437	4.5307	292.17	6792.91
94	8836	830584	9.6954	4.5468	295.31	6939.78
95	9025	857375	9.7468	4.5629	298.45	7088.22
96	9216	884736	9.7980	4.5789	301.59	7238.23
97	9409	912673	9.8489	4.5947	304.73	7389.81
98	9604	941192	9.8995	4.6104	307.88	7542.96
99	9801	970299	9.9499	4.6261	311.02	7697.69
100	10000	1000000	10.0000	4.6416	314.16	7853.98
101	10201	1030301	10.0499	4.6570	317.30	8011.85
102	10404	1061208	10.0995	4.6723	320.44	8171.28
103	10609	1092727	10.1489	4.6875	323.58	8332.29
104	10816	1124864	10.1980	4.7027	326.73	8494.87
105	11025	1157625	10.2470	4.7177	329.87	8659.01
106	11236	1191016	10.2956	4.7326	333.01	8824.73
107	11449	1225043	10.3441	4.7475	336.15	8992.02
108	11664	1259712	10.3923	4.7622	339.29	9160.88
109	11881	1295029	10.4403	4.7769	342.43	9331.32
110	12100	1331000	10.4881	4.7914	345.58	9503.32
111	12321	1367631	10.5357	4.8059	348.72	9676.89
112	12544	1404928	10.5830	4.8203	351.86	9852.03
113	12769	1442897	10.6301	4.8346	355.00	10028.7
114	12996	1481544	10.6771	4.8488	358.14	10207.0
115	13225	1520875	10.7238	4.8629	361.28	10386.9
116	13456	1560896	10.7703	4.8770	364.42	10568.3
117	13689	1601613	10.8167	4.8910	367.57	10751.3
118	13924	1643032	10.8628	4.9049	370.71	10935.9
119	14161	1685159	10.9087	4.9187	373.85	11122.0
120	14400	1728000	10.9545	4.9324	376.99	11309.7

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	CIRCLE	
					Circum.	Area
121	14641	1771561	11.0000	4.9461	380.13	11499.0
122	14884	1815848	11.0454	4.9597	383.27	11689.9
123	15129	1860867	11.0905	4.9732	386.42	11882.3
124	15376	1906624	11.1355	4.9866	389.56	12076.3
125	15625	1953125	11.1803	5.0000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	395.84	12469.0
127	16129	2048383	11.2694	5.0265	398.98	12667.7
128	16384	2097152	11.3137	5.0397	402.12	12868.0
129	16641	2146689	11.3578	5.0528	405.27	13069.8
130	16900	2197000	11.4018	5.0658	408.41	13273.2
131	17161	2248091	11.4455	5.0788	411.55	13478.2
132	17424	2299968	11.4891	5.0916	414.69	13684.8
133	17689	2352637	11.5326	5.1045	417.83	13892.9
134	17956	2406104	11.5758	5.1172	420.97	14102.6
135	18225	2460375	11.6190	5.1299	424.12	14313.9
136	18496	2515456	11.6619	5.1426	427.26	14526.7
137	18769	2571353	11.7047	5.1551	430.40	14741.1
138	19044	2628072	11.7473	5.1676	433.54	14957.1
139	19321	2685619	11.7898	5.1801	436.68	15174.7
140	19600	2744000	11.8322	5.1925	439.82	15393.8
141	19881	2803221	11.8743	5.2048	442.96	15614.5
142	20164	2863288	11.9164	5.2171	446.11	15836.8
143	20449	2924207	11.9583	5.2293	449.25	16060.6
144	20736	2985984	12.0000	5.2415	452.39	16286.0
145	21025	3048625	12.0416	5.2536	455.53	16513.0
146	21316	3112136	12.0830	5.2656	458.67	16741.5
147	21609	3176523	12.1244	5.2776	461.81	16971.7
148	21904	3241792	12.1655	5.2896	464.96	17203.4
149	22201	3307949	12.2066	5.3015	468.10	17436.6
150	22500	3375000	12.2474	5.3133	471.24	17671.5
151	22801	3442951	12.2882	5.3251	474.38	17907.9
152	23104	3511808	12.3288	5.3368	477.52	18145.8
153	23409	3581577	12.3693	5.3485	480.66	18385.4
154	23716	3652264	12.4097	5.3601	483.81	18626.5
155	24025	3723875	12.4499	5.3717	486.95	18869.2
156	24336	3796416	12.4900	5.3832	490.09	19113.4
157	24649	3869893	12.5300	5.3947	493.23	19359.3
158	24964	3944312	12.5698	5.4061	496.37	19606.7
159	25281	4019679	12.6095	5.4175	499.51	19855.7
160	25600	4096000	12.6491	5.4288	502.65	20106.2

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Circular Areas of Nos. from 1 to 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
161	25921	4173281	12.6886	5.4401	505.80	20358.3
162	26244	4251528	12.7279	5.4514	508.94	20612.0
163	26569	4330747	12.7671	5.4626	512.08	20867.2
164	26896	4410944	12.8062	5.4737	515.22	21124.1
165	27225	4492125	12.8452	5.4848	518.36	21382.5
166	27556	4574296	12.8841	5.4959	521.50	21642.4
167	27889	4657463	12.9228	5.5069	524.65	21904.0
168	28224	4741632	12.9615	5.5178	527.79	22167.1
169	28561	4826809	13.0000	5.5288	530.93	22431.8
170	28900	4913000	13.0384	5.5397	534.07	22698.0
171	29241	5000211	13.0767	5.5505	537.21	22965.8
172	29584	5088448	13.1149	5.5613	540.35	23235.2
173	29929	5177717	13.1529	5.5721	543.50	23506.2
174	30276	5268024	13.1909	5.5828	546.64	23778.7
175	30625	5359375	13.2288	5.5934	549.78	24052.8
176	30976	5451776	13.2665	5.6041	552.92	24328.5
177	31329	5545233	13.3041	5.6147	556.06	24605.7
178	31684	5639752	13.3417	5.6252	559.20	24884.6
179	32041	5735339	13.3791	5.6357	562.35	25164.9
180	32400	5832000	13.4164	5.6462	565.49	25446.9
181	32761	5929741	13.4536	5.6567	568.63	25730.4
182	33124	6028568	13.4907	5.6671	571.77	26015.5
183	33489	6128487	13.5277	5.6774	574.91	26302.2
184	33856	6229504	13.5647	5.6877	578.05	26590.4
185	34225	6331625	13.6015	5.6980	581.19	26880.3
186	34596	6434856	13.6382	5.7083	584.34	27171.6
187	34969	6539203	13.6748	5.7185	587.48	27464.6
188	35344	6644672	13.7113	5.7287	590.62	27759.1
189	35721	6751269	13.7477	5.7388	593.76	28055.2
190	36100	6859000	15.7840	5.7489	596.90	28352.9
191	36481	6967871	13.8203	5.7590	600.04	28652.1
192	36864	7077888	13.8564	5.7690	603.19	28952.9
193	37249	7189057	13.8924	5.7790	606.33	29255.3
194	37636	7301384	13.9284	5.7890	609.47	29559.2
195	38025	7414875	13.9642	5.7989	612.61	29864.8
196	38416	7529536	14.0000	5.8088	615.75	30171.9
197	38809	7645373	14.0357	5.8186	618.89	30480.5
198	39204	7762392	14.0712	5.8285	622.04	30790.7
199	39601	7880599	14.1067	5.8383	625.18	31102.6
200	40000	8000000	14.1421	5.8480	628.32	31415.9

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
201	40401	8120601	14.1774	5.8578	631.46	31730.9
202	40804	8242408	14.2127	5.8675	634.60	32047.4
203	41209	8365427	14.2478	5.8771	637.74	32365.5
204	41616	8489664	14.2829	5.8868	640.89	32685.1
205	42025	8615125	14.3178	5.8964	644.03	33006.4
206	42436	8741816	14.3527	5.9059	647.17	33329.2
207	42849	8869743	14.3875	5.9155	650.31	33653.5
208	43264	8998912	14.4222	5.9250	653.45	33979.5
209	43681	9129329	14.4568	5.9345	656.59	34307.0
210	44100	9261000	14.4914	5.9439	659.73	34636.1
211	44521	9393931	14.5258	5.9533	662.88	34966.7
212	44944	9528128	14.5602	5.9627	666.02	35298.9
213	45369	9663597	14.5945	5.9721	669.16	35632.7
214	45796	9800344	14.6287	5.9814	672.30	35968.1
215	46225	9938375	14.6629	5.9907	675.44	36305.0
216	46656	10077696	14.6969	6.0000	678.58	36643.5
217	47089	10218313	14.7309	6.0092	681.73	36983.6
218	47524	10360232	14.7648	6.0185	684.87	37325.3
219	47961	10503459	14.7986	6.0277	688.01	37668.5
220	48400	10648000	14.8324	6.0368	691.15	38013.3
221	48841	10793861	14.8661	6.0459	694.29	38359.6
222	49284	10941048	14.8997	6.0550	697.43	38707.6
223	49729	11089567	14.9332	6.0641	700.58	39057.1
224	50176	11239424	14.9666	6.0732	703.72	39408.1
225	50625	11390625	15.0000	6.0822	706.86	39760.8
226	51076	11543176	15.0333	6.0912	710.00	40115.0
227	51529	11697083	15.0665	6.1002	713.14	40470.8
228	51984	11852352	15.0997	6.1091	716.28	40828.1
229	52441	12008989	15.1327	6.1180	719.42	41187.1
230	52900	12167000	15.1658	6.1269	722.57	41547.6
231	53361	12326391	15.1987	6.1358	725.71	41909.6
232	53824	12487168	15.2315	6.1446	728.85	42273.3
233	54289	12649337	15.2643	6.1534	731.99	42638.5
234	54756	12812904	15.2971	6.1622	735.13	43005.3
235	55225	12977875	15.3297	6.1710	738.27	43373.6
236	55696	13144256	15.3623	6.1797	741.42	43743.5
237	56169	13312053	15.3948	6.1885	744.56	44115.0
238	56644	13481272	15.4272	6.1972	747.70	44488.1
239	57121	13651919	15.4596	6.2058	750.84	44862.7
240	57600	13824000	15.4919	6.2145	753.98	45238.9

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
241	58081	13997521	15.5242	6.2231	757.12	45616.7
242	58564	14172488	15.5563	6.2317	760.27	45996.1
243	59049	14348907	15.5885	6.2403	763.41	46377.0
244	59536	14526784	15.6205	6.2488	766.55	46759.5
245	60025	14706125	15.6525	6.2573	769.69	47143.5
246	60516	14886936	15.6844	6.2658	772.83	47529.2
247	61009	15069223	15.7162	6.2743	775.97	47916.4
248	61504	15252992	15.7480	6.2828	779.12	48305.1
249	62001	15438249	15.7797	6.2912	782.26	48695.5
250	62500	15625000	15,8114	6.2996	785.40	49087.4
251	63001	15813251	15.8430	6.3080	788.54	49480.9
252	63504	16003008	15.8745	6.3164	791.68	49875.9
253	64009	16194277	15.9060	6.3247	794.82	50272.6
254	64516	16387064	15.9374	6.3330	797.96	50670.7
255	65025	16581375	15.9687	6.3413	801.11	51070.5
256	65536	16777216	16.0000	6.3496	804.25	51471.9
257	66049	16974593	16.0312	6.3579	807.39	51874.8
258	66564	17173512	16.0624	6.3661	810.53	52279.2
259	67081	17373979	16.0935	6.3743	813.67	52685.3
260	67600	17576000	16.1245	6.3825	816.81	53092.9
261	68121	17779581	16.1555	6.3907	819.96	53502.1
262	68644	17984728	16.1864	6.3988	823.10	53912.9
263	69169	18191447	16.2173	6.4070	826.24	54325.2
264	69696	18399744	16.2481	6.4151	829.38	54739.1
265	70225	18609625	16.2788	6.4232	832.52	55154.6
266	70756	18821096	16.3095	6.4312	835.66	55571.6
267	71289	19034163	16.3401	6.4393	838.81	55990.3
268	71824	19248832	16.3707	6.4473	841.95	56410.4
269	72361	19465109	16.4012	6.4553	845.09	56832.2
270	72900	19683000	16.4317	6.4633	848.23	57255.5
271	73441	19902511	16.4621	6.4713	851.37	57680.4
272	73984	20123648	16.4924	6.4792	854.51	58106.9
273	74529	20346417	16.5227	6.4872	857.66	58534.9
274	75076	20570824	16.5529	6.4951	860.80	58964.6
275	75625	20796875	16.5831	6.5030	863.94	59395.7
276	76176	21024576	16.6132	6.5108	867.08	59828.5
277	76729	21253933	16.6433	6.5187	870.22	60262.8
278	77284	21484952	16.6733	6.5265	873.36	60698.7
279	77841	21717639	16.7033	6.5343	876.50	61136.2
280	78400	21952000	16.7332	6.5421	879.65	61575.2

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
281	78961	22188041	16.7631	6.5499	882.79	62015.8
282	79524	22425768	16.7929	6.5577	885.93	62458.0
283	80089	22665187	16.8226	6.5654	889.07	62901.8
284	80656	22906304	16.8523	6.5731	892.21	63347.1
285	81225	23149125	16.8819	6.5808	895.35	63794.0
286	81796	23393656	16.9115	6.5885	898.50	64242.4
287	82369	23639903	16.9411	6.5962	901.64	64692.5
288	82944	23887872	16.9706	6.6039	904.78	65144.1
289	83521	24137569	17.0000	6.6115	907.92	65597.2
290	84100	24389000	17.0294	6.6191	911.06	66052.0
291	84681	24642171	17.0587	6.6267	914.20	66508.3
292	85264	24897088	17.0880	6.6343	917.35	66966.2
293	85849	25153757	17.1172	6.6419	920.49	67425.6
294	86436	25412184	17.1464	6.6494	923.63	67886.7
295	87025	25672375	17.1756	6.6569	926.77	68349.3
296	87616	25934336	17.2047	6.6644	929.91	68813.5
297	88209	26198073	17.2337	6.6719	933.05	69279.2
298	88804	26463592	17.2627	6.6794	936.19	69746.5
299	89401	26730899	17.2916	6.6869	939.34	70215.4
300	90000	27000000	17.3205	6.6943	942.48	70685.8
301	90601	27270901	17.3494	6.7018	945.62	71157.9
302	91204	27543608	17.3781	6.7092	948.76	71631.5
303	91809	27818127	17.4069	6.7166	951.90	72106.6
304	92416	28094464	17.4356	6.7240	955.04	72583.4
305	93025	28372625	17.4642	6.7313	958.19	73061.7
306	93636	28652616	17.4929	6.7387	961.33	73541.5
307	94249	28934443	17.5214	6.7460	964.47	74023.0
308	94864	29218112	17.5499	6.7533	967.61	74506.0
309	95481	29503629	17.5784	6.7606	970.75	74990.6
310	96100	29791000	17.6068	6.7679	973.89	75476.8
311	96721	30080231	17.6352	6.7752	977.04	75964.5
312	97344	30371328	17.6635	6.7824	980.18	76453.8
313	97969	30664297	17.6918	6.7897	983.32	76944.7
314	98596	30959144	17.7200	6.7969	986.46	77437.1
315	99225	31255875	17.7482	6.8041	989.60	77931.1
316	99856	31554496	17.7764	6.8113	992.74	78426.7
317	100489	31855013	17.8045	6.8185	995.88	78923.9
318	101124	32157432	17.8326	6.8256	999.03	79422.6
319	101761	32461759	17.8606	6.8328	1002.20	79922.9
320	102400	32768000	17.8885	6.8399	1005.30	80424.8

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
321	103041	33076161	17.9165	6.8470	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	1096.4	95662.3
350	122500	42875000	18.7083	7.0473	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	1121.5	100098
358	128164	45882712	18.9209	7.1006	1124.7	100660
359	128881	46268279	18.9473	7.1072	1127.8	101223
360	129600	46656000	18.9737	7.1138	1131.0	101788

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
361	130321	47045881	19.0000	7.1204	1134.1	102354
362	131044	47437928	19.0263	7.1269	1137.3	102922
363	131769	47832147	19.0526	7.1335	1140.4	103491
364	132496	48228544	19.0788	7.1400	1143.5	104062
365	133225	48627125	19.1050	7.1466	1146.7	104635
366	133956	49027896	19.1311	7.1531	1149.8	105209
367	134689	49430863	19.1572	7.1596	1153.0	105785
368	135424	49836032	19.1833	7.1661	1156.1	106362
369	136161	50243409	19.2094	7.1726	1159.2	106941
370	136900	50653000	19.2354	7.1791	1162.4	107521
371	137641	51064811	19.2614	7.1855	1165.5	108103
372	138384	51478848	19.2873	7.1920	1168.7	108687
373	139129	51895117	19.3132	7.1984	1171.8	109272
374	139876	52313624	19.3391	7.2048	1175.0	109858
375	140625	52734375	19.3649	7.2112	1178.1	110447
376	141376	53157376	19.3907	7.2177	1181.2	111036
377	142129	53582633	19.4165	7.2240	1184.4	111628
378	142884	54010152	19.4422	7.2304	1187.5	112221
379	143641	54439939	19.4679	7.2368	1190.7	112815
380	144400	54872000	19.4936	7.2432	1193.8	113411
381	145161	55306341	19.5192	7.2495	1196.9	114009
382	145924	55742968	19.5448	7.2558	1200.1	114608
383	146689	56181887	19.5704	7.2622	1203.2	115209
384	147456	56623104	19.5959	7.2685	1206.4	115812
385	148225	57066625	19.6214	7.2748	1209.5	116416
386	148996	57512456	19.6469	7.2811	1212.7	117021
387	149769	57960603	19.6723	7.2874	1215.8	117628
388	150544	58411072	19.6977	7.2936	1218.9	118237
389	151321	58863869	19.7231	7.2999	1222.1	118847
390	152100	59319000	19.7484	7.3061	1225.2	119459
391	152881	59776471	19.7737	7.3124	1228.4	120072
392	153664	60236288	19.7990	7.3186	1231.5	120687
393	154449	60698457	19.8242	7.3248	1234.6	121304
394	155236	61162984	19.8494	7.3310	1237.8	121922
395	156025	61629875	19.8746	7.3372	1240.9	122542
396	156816	62099136	19.8997	7.3434	1244.1	123163
397	157609	62570773	19.9249	7.3496	1247.2	123786
398	158404	63044792	19.9499	7.3558	1250.4	124410
399	159201	63521199	19.9750	7.3619	1253.5	125036
400	160000	64000000	20.0000	7.3684	1256.6	125664

Squares, Cubes, Square Roots, Cube Roots. Circumferences, and Circular Areas of Nos. from 1 to 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
401	160801	64481201	20.0250	7.3742	1259.8	126293
402	161604	64964808	20.0499	7.3803	1262.9	126923
403	162409	65450827	20.0749	7.3864	1266.1	127556
404	163216	65939264	20.0998	7.3925	1269.2	128190
405	164025	66430125	20.1246	7.3986	1272.3	128825
406	164836	66923416	20.1494	7.4047	1275.5	129462
407	165649	67419143	20.1742	7.4108	1278.6	130100
408	166464	67917312	20.1990	7.4169	1281.8	130741
409	167281	68417929	20.2237	7.4229	1284.9	131382
410	168100	68921000	20.2485	7.4290	1288.1	132025
411	168921	69426531	20.2731	7.4350	1291.2	132670
412	169744	69934528	20.2978	7.4410	1294.3	133317
413	170569	70444997	20.3224	7.4470	1297.5	133965
414	171396	70957944	20.3470	7.4530	1300.6	134614
415	172225	71473375	20.3715	7.4590	1303.8	135265
416	173056	71991296	20.3961	7.4650	1306.9	135918
417	173889	72511713	20.4206	7.4710	1310.0	136572
418	174724	73034632	20.4450	7.4770	1313.2	137228
419	175561	73560059	20.4695	7.4829	1316.3	137885
420	176400	74088000	20.4939	7.4889	1319.5	138544
421	177241	74618461	20.5183	7.4948	1322.6	139205
422	178084	75151448	20.5426	7.5007	1325.8	139867
423	178929	75686967	20.5670	7.5067	1328.9	140531
424.	179776	76225024	20.5913	7.5126	1332.0	141196
425	180625	76765625	20.6155	7.5185	1335.2	141863
426	181476	77308776	20.6398	7.5244	1338.3	142531
427	182329	77854483	20.6640	7.5302	1341.5	143201
428	183184	78402752	20.6882	7.5361	1344.6	143872
429	184041	78953589	20.7123	7.5420	1347.7	144545
430	184900	79507000	20.7364	7.5478	1350.9	145220
431	185761	80062991	20.7605	7.5537	1354.0	145896
432	186624	80621568	20.7846	7.5595	1357.2	146574
433	187489	81182737	20.8087	7.5654	1360.3	147254
434	188356	81746504	20.8327	7.5712	1363.5	147934
435	189225	82312875	20.8567	7.5770	1366.6	148617
436	190096	82881856	20.8806	7.5828	1369.7	149301
437	190969	83453453	20.9045	7.5886	1372.9	149987
438	191844	84027672	20.9284	7.5944	1376.0	150674
439	192721	84604519	20.9523	7.6001	1379.2	151363
440	193600	85184000	20.9762	7.6059	1382.3	152053

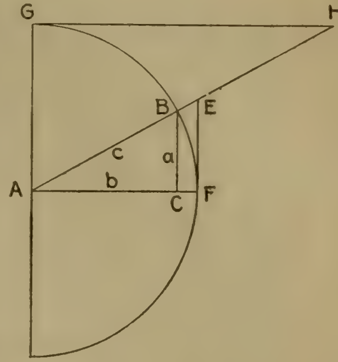
Squares, Cubes, Square Roots, Cube Roots, Circumferences and Circular Areas of Nos. from 1 to 520

No.	Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
441	194481	85766121	21.0000	7.6117	1385.4	152745
442	195364	86350888	21.0238	7.6174	1388.6	153439
443	196249	86938307	21.0476	7.6232	1391.7	154134
444	197136	87528384	21.0713	7.6289	1394.9	154830
445	198025	88121125	21.0950	7.6346	1398.0	155528
446	198916	88716536	21.1187	7.6403	1401.2	156228
447	199809	89314623	21.1424	7.6460	1404.3	156930
448	200704	89915392	21.1660	7.6517	1407.4	157633
449	201601	90518849	21.1896	7.6574	1410.6	158337
450	202500	91125000	21.2132	7.6631	1413.7	159043
451	203401	91733851	21.2368	7.6688	1416.9	159751
452	204304	92345408	21.2603	7.6744	1420.0	160460
453	205209	92959677	21.2838	7.6801	1423.1	161171
454	206116	93576664	21.3073	7.6857	1426.3	161883
455	207025	94196375	21.3307	7.6914	1429.4	162597
456	207936	94818816	21.3542	7.6970	1432.6	163313
457	208849	95443993	21.3776	7.7026	1435.7	164030
458	209764	96071912	21.4009	7.7082	1438.9	164748
459	210681	96702579	21.4243	7.7138	1442.0	165468
460	211600	97336000	21.4476	7.7194	1445.1	166190
461	212521	97972181	21.4709	7.7250	1448.3	166914
462	213444	98611128	21.4942	7.7306	1451.4	167639
463	214369	99252847	21.5174	7.7362	1454.6	168365
464	215296	99897344	21.5407	7.7418	1457.7	169093
465	216225	100544625	21.5639	7.7473	1460.8	169823
466	217156	101194696	21.5870	7.7529	1464.0	170554
467	218089	101847563	21.6102	7.7584	1467.1	171287
468	219024	102503232	21.6333	7.7639	1470.3	172021
469	219961	103161709	21.6564	7.7695	1473.4	172757
470	220900	103823000	21.6795	7.7750	1476.5	173494
471	221841	104487111	21.7025	7.7805	1479.7	174234
472	222784	105154048	21.7256	7.7860	1482.8	174974
473	223729	105823817	21.7486	7.7915	1486.0	175716
474	224676	106496424	21.7715	7.7970	1489.1	176460
475	225625	107171875	21.7945	7.8025	1492.3	177205
476	226576	107850176	21.8174	7.8079	1495.4	177952
477	227529	108531333	21.8403	7.8134	1498.5	178701
478	228484	109215352	21.8632	7.8188	1501.7	179451
479	229441	109902239	21.8861	7.8243	1504.8	180203
480	230400	110592000	21.9089	7.8297	1508.0	180956

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
481	231361	111284641	21.9317	7.8352	1511.1	181711
482	232324	111980168	21.9545	7.8406	1514.3	182467
483	233289	112678587	21.9773	7.8460	1517.4	183225
484	234256	113379904	22.0000	7.8514	1520.5	183984
485	235225	114084125	22.0227	7.8568	1523.7	184745
486	236196	114791256	22.0454	7.8622	1526.8	185508
487	237169	115501303	22.0681	7.8676	1530.0	186272
488	238144	116214272	22.0907	7.8730	1533.1	187038
489	239121	116930169	22.1133	7.8784	1536.2	187805
490	240100	117649000	22.1359	7.8837	1539.4	188574
491	241081	118370771	22.1585	7.8891	1542.5	189345
492	242064	119095488	22.1811	7.8944	1545.7	190117
493	243049	119823157	22.2036	7.8998	1548.8	190890
494	244036	120553784	22.2261	7.9051	1551.9	191665
495	245025	121287375	22.2486	7.9105	1555.1	192442
496	246016	122023936	22.2711	7.9158	1558.2	193221
497	247009	122763473	22.2935	7.9211	1561.4	194000
498	248004	123505992	22.3159	7.9264	1564.5	194782
499	249001	124251499	22.3383	7.9317	1567.7	195565
500	250000	125000000	22.3607	7.9370	1570.8	196350
501	251001	125751501	22.3830	7.9423	1573.9	197136
502	252004	126506008	22.4054	7.9476	1577.1	197923
503	253009	127263527	22.4277	7.9528	1580.2	198713
504	254016	128024064	22.4499	7.9581	1583.4	199504
505	255025	128787625	22.4722	7.9634	1586.5	200296
506	256036	129554216	22.4944	7.9686	1589.7	201090
507	257049	130323843	22.5167	7.9739	1592.8	201886
508	258064	131096512	22.5389	7.9791	1595.9	202683
509	259081	131872229	22.5610	7.9843	1599.1	203482
510	260100	132651000	22.5832	7.9896	1602.2	204282
511	261121	133432831	22.6053	7.9948	1605.4	205084
512	262144	134217728	22.6274	8.0000	1608.5	205887
513	263169	135005697	22.6495	8.0052	1611.6	206692
514	264196	135796744	22.6716	8.0104	1614.8	207499
515	265225	136590875	22.6936	8.0156	1617.9	208307
516	266256	137388096	22.7156	8.0208	1621.1	209117
517	267289	138188413	22.7376	8.0260	1624.2	209928
518	268324	138991832	22.7596	8.0311	1627.3	210741
519	269361	139798359	22.7816	8.0363	1630.5	211556
520	270400	140608000	22.8035	8.0415	1633.6	212372

TABLE 59. TRIGONOMETRIC FUNCTIONS AND THE SOLUTION OF TRIANGLES



In the accompanying figure the trigonometric functions of the angle A between the lines $B\,A$ and $A\,C$ are as follows;

$$\begin{aligned}\sin A &= B\,C\\ \cos A &= A\,C\\ \tan A &= E\,F\\ \cot A &= G\,H\\ \sec A &= A\,E\\ \operatorname{cosec} A &= A\,H\\ \text{ex-sec } A &= B\,E\end{aligned}$$

In the right-angled triangle $A\,B\,C$ let a equal the side $B\,C$ opposite the angle A; let b equal the side $A\,C$ opposite the angle B; let c equal $A\,B$, the side opposite the angle C.

Let $C = 90°$
The following formulæ apply to right-angled triangles:

Angles. $A + B + C = 180°$

$$A + B = 90°$$
$$A = 90° - B$$
$$B = 90° - A$$

Sides. $a = c \sin A = b \tan A$

$$a = \sqrt{(c+b)\ (c-b)}$$
$$b = c \cos. A = \frac{a}{\tan A}$$
$$b = \sqrt{(c+a)\ (c-a)}$$
$$c = \frac{a}{\sin A} = \frac{b}{\cos A}$$
$$c = \sqrt{a^2 + b^2}$$

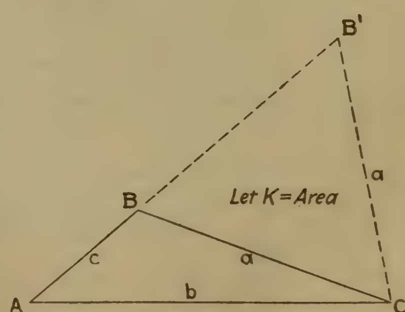
$$\sin A = \frac{a}{c}$$
$$\cos A = \frac{b}{c}$$
$$\tan A = \frac{a}{b}$$

Area

$$\text{area} = \frac{a\,b}{2}$$

Oblique Triangles.

Note. Where an angle is more than 90° its sine, cosine, and tangent are equal to that of the angle (180° – the angle in question); that is, if the sine of 120° is desired take the sine of (180° – 120°) = 60°.



Given	Desired	Formulæ
A, B, a	C, b	$C = 180 - (A + B)$; $b = \dfrac{a}{\sin A} \sin B$
	c, K	$c = \dfrac{a}{\sin A} \sin (A + B)$; $K = \dfrac{a^2 \sin B \sin C}{2 \sin A}$
A, a, b	B, C	$\sin B = \dfrac{\sin A}{a} b$; $C = 180° - (A + B)$
	c	$c = \dfrac{a}{\sin A} \sin C$
		Two solutions are possible with B′ as an acute angle and B as an obtuse angle
C, a, b	$\frac{1}{2}(A+B)$	$\frac{1}{2}(A+B) = 90° - \frac{1}{2} C$
	$\frac{1}{2}(A-B)$	$\tan \frac{1}{2}(A-B) = \dfrac{a-b}{a+b} \tan \frac{1}{2}(A+B)$
	$A\ B$	$A = \frac{1}{2}(A+B) + \frac{1}{2}(A-B)$
		$B = \frac{1}{2}(A+B) - \frac{1}{2}(A-B)$
	c	$c = (a-b) \dfrac{\sin \frac{1}{2}(A+B)}{\sin \frac{1}{2}(A-B)}$
	K	$K = \frac{1}{2} ab \sin C$
a, b, c	B	In the following formula $s = \frac{1}{2}(a+b+c)$
		$\sin \frac{1}{2} B = \sqrt{\dfrac{(s-a)(s-c)}{ac}}$
		$\sin B = \dfrac{2\sqrt{s(s-a)(s-b)(s-c)}}{ac}$
	K	$K = \sqrt{s(s-a)(s-b)(s-c)}$

TABLE 60

′	0° Tan.	0° Co-tan.	1° Tan.	1° Co-tan.	2° Tan.	2° Co-tan.	3° Tan.	3° Co-tan.	′
0	.00000	Infinite.	.01746	57.2900	.03492	28.6363	.05241	19.0811	60
1	.00029	3437.750	.01775	56.3506	.03521	28.3994	.05270	18.9755	59
2	.00058	1718.870	.01804	55.4415	.03550	28.1664	.05299	18.8711	58
3	.00087	1145.920	.01833	54.5613	.03579	27.9372	.05328	18.7678	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	33
28	.00814	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	15
46	.01338	74.7292	.03084	32.4213	.04832	20.6932	.06584	15.1893	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	1
60	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	0
′	Co-tan. 89°	Tan. 89°	Co-tan. 88°	Tan. 88°	Co-tan. 87°	Tan. 87°	Co-tan. 86°	Tan. 86°	′

′	4° Tan.	4° Co-tan.	5° Tan.	5° Co-tan.	6° Tan.	6° Co-tan.	7° Tan.	7° Co-tan.	′
0	.06993	14.3007	.08749	11.4301	.10510	9.51436	.12278	8.14435	60
1	.07022	14.2411	.08778	11.3919	.10540	9.48781	.12308	8.12481	59
2	.07051	14.1821	.08807	11.3540	.10569	9.46141	.12338	8.10536	58
3	.07080	14.1235	.08837	11.3163	.10599	9.43515	.12367	8.08600	57
4	.07110	14.0655	.08866	11.2789	.10628	9.40904	.12397	8.06674	56
5	.07139	14.0079	.08895	11.2417	.10657	9.38307	.12426	8.04756	55
6	.07168	13.9507	.08925	11.2048	.10687	9.35724	.12456	8.02848	54
7	.07197	13.8940	.08954	11.1681	.10716	9.33154	.12485	8.00948	53
8	.07227	13.8378	.08983	11.1316	.10746	9.30599	.12515	7.99058	52
9	.07256	13.7821	.09013	11.0954	.10775	9.28058	.12544	7.97176	51
10	.07285	13.7267	.09042	11.0594	.10805	9.25530	.12574	7.95302	50
11	.07314	13.6719	.09071	11.0237	.10834	9.23016	.12603	7.93438	49
12	.07344	13.6174	.09101	10.9882	.10863	9.20516	.12633	7.91582	48
13	.07373	13.5634	.09130	10.9529	.10893	9.18028	.12662	7.89734	47
14	.07402	13.5098	.09159	10.9178	.10922	9.15554	.12692	7.87895	46
15	.07431	13.4566	.09189	10.8829	.10952	9.13093	.12722	7.86064	45
16	.07461	13.4039	.09218	10.8483	.10981	9.10646	.12751	7.84242	44
17	.07490	13.3515	.09247	10.8139	.11011	9.08211	.12781	7.82428	43
18	.07519	13.2996	.09277	10.7797	.11040	9.05789	.12810	7.80622	42
19	.07548	13.2480	.09306	10.7457	.11070	9.03379	.12840	7.78825	41
20	.07578	13.1969	.09335	10.7119	.11099	9.00983	.12869	7.77035	40
21	.07607	13.1461	.09365	10.6783	.11128	8.98598	.12899	7.75254	39
22	.07636	13.0958	.09394	10.6450	.11158	8.96227	.12929	7.73480	38
23	.07665	13.0458	.09423	10.6118	.11187	8.93867	.12958	7.71715	37
24	.07695	12.9962	.09453	10.5789	.11217	8.91520	.12988	7.69957	36
25	.07724	12.9469	.09482	10.5462	.11246	8.89185	.13017	7.68208	35
26	.07753	12.8981	.09511	10.5136	.11276	8.86862	.13047	7.66466	34
27	.07782	12.8496	.09541	10.4813	.11305	8.84551	.13076	7.64732	33
28	.07812	12.8014	.09570	10.4491	.11335	8.82252	.13106	7.63005	32
29	.07841	12.7536	.09600	10.4172	.11364	8.79964	.13136	7.61287	31
30	.07870	12.7062	.09629	10.3854	.11394	8.77689	.13165	7.59575	30
31	.07899	12.6591	.09658	10.3538	.11423	8.75425	.13195	7.57872	29
32	.07929	12.6124	.09688	10.3224	.11452	8.73172	.13224	7.56176	28
33	.07958	12.5660	.09717	10.2913	.11482	8.70931	.13254	7.54487	27
34	.07987	12.5199	.09746	10.2602	.11511	8.68701	.13284	7.52806	26
35	.08017	12.4742	.09776	10.2294	.11541	8.66482	.13313	7.51132	25
36	.08046	12.4288	.09805	10.1988	.11570	8.64275	.13343	7.49465	24
37	.08075	12.3838	.09834	10.1683	.11600	8.62078	.13372	7.47806	23
38	.08104	12.3390	.09864	10.1381	.11629	8.59893	.13402	7.46154	22
39	.08134	12.2946	.09893	10.1080	.11659	8.57718	.13432	7.44509	21
40	.08163	12.2505	.09923	10.0780	.11688	8.55555	.13461	7.42871	20
41	.08192	12.2067	.09952	10.0483	.11718	8.53402	.13491	7.41240	19
42	.08221	12.1632	.09981	10.0187	.11747	8.51259	.13521	7.39616	18
43	.08251	12.1201	.10011	9.98931	.11777	8.49128	.13550	7.37999	17
44	.08280	12.0772	.10040	9.96007	.11806	8.47007	.13580	7.36389	16
45	.08309	12.0346	.10069	9.93101	.11836	8.44896	.13609	7.34786	15
46	.08339	11.9923	.10099	9.90211	.11865	8.42795	.13639	7.33190	14
47	.08368	11.9504	.10128	9.87338	.11895	8.40705	.13669	7.31600	13
48	.08397	11.9087	.10158	9.84482	.11924	8.38625	.13698	7.30018	12
49	.08427	11.8673	.10187	9.81641	.11954	8.36555	.13728	7.28442	11
50	.08456	11.8262	.10216	9.78817	.11983	8.34496	.13758	7.26873	10
51	.08485	11.7853	.10246	9.76009	.12013	8.32446	.13787	7.25310	9
52	.08514	11.7448	.10275	9.73217	.12042	8.30406	.13817	7.23754	8
53	.08544	11.7045	.10305	9.70441	.12072	8.28376	.13846	7.22204	7
54	.08573	11.6645	.10334	9.67680	.12101	8.26355	.13876	7.20661	6
55	.08602	11.6248	.10363	9.64935	.12131	8.24345	.13906	7.19125	5
56	.08632	11.5853	.10393	9.62205	.12160	8.22344	.13935	7.17594	4
57	.08661	11.5461	.10422	9.59490	.12190	8.20352	.13965	7.16071	3
58	.08690	11.5072	.10452	9.56791	.12219	8.18370	.13995	7.14553	2
59	.08720	11.4685	.10481	9.54106	.12249	8.16398	.14024	7.13042	1
60	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	85°		84°		83°		82°		

′	8° Tan.	8° Co-tan.	9° Tan.	9° Co-tan.	10° Tan.	10° Co-tan.	11° Tan.	11° Co-tan.	′
0	.14054	7.11537	.15838	6.31375	.17633	5.67128	.19438	5.14455	60
1	.14084	7.10038	.15868	6.30189	.17663	5.66165	.19468	5.13658	59
2	.14113	7.08546	.15898	6.29007	.17693	5.65205	.19498	5.12862	58
3	.14143	7.07059	.15928	6.27829	.17723	5.64248	.19529	5.12069	57
4	.14173	7.05579	.15958	6.26655	.17753	5.63295	.19559	5.11279	56
5	.14202	7.04105	.15988	6.25486	.17783	5.62344	.19589	5.10490	55
6	.14232	7.02637	.16017	6.24321	.17813	5.61397	.19619	5.09704	54
7	.14262	7.01174	.16047	6.23160	.17843	5.60452	.19649	5.08921	53
8	.14291	6.99718	.16077	6.22003	.17873	5.59511	.19680	5.08139	52
9	.14321	6.98268	.16107	6.20851	.17903	5.58573	.19710	5.07360	51
10	.14351	6.96823	.16137	6.19703	.17933	5.57638	.19740	5.06584	50
11	.14381	6.95385	.16167	6.18559	.17963	5.56706	.19770	5.05809	49
12	.14410	6.93952	.16196	6.17419	.17993	5.55777	.19801	5.05037	48
13	.14440	6.92525	.16226	6.16283	.18023	5.54851	.19831	5.04267	47
14	.14470	6.91104	.16256	6.15151	.18053	5.53927	.19861	5.03499	46
15	.14499	6.89688	.16286	6.14023	.18083	5.53007	.19891	5.02734	45
16	.14529	6.88278	.16316	6.12899	.18113	5.52090	.19921	5.01971	44
17	.14559	6.86874	.16346	6.11779	.18143	5.51176	.19952	5.01210	43
18	.14588	6.85475	.16376	6.10664	.18173	5.50264	.19982	5.00451	42
19	.14618	6.84082	.16405	6.09552	.18203	5.49356	.20012	4.99695	41
20	.14648	6.82694	.16435	6.08444	.18233	5.48451	.20042	4.98940	40
21	.14678	6.81312	.16465	6.07340	.18263	5.47548	.20073	4.98188	39
22	.14707	6.79936	.16495	6.06240	.18293	5.46648	.20103	4.97438	38
23	.14737	6.78564	.16525	6.05143	.18323	5.45751	.20133	4.96690	37
24	.14767	6.77199	.16555	6.04051	.18353	5.44857	.20164	4.95945	36
25	.14796	6.75838	.16585	6.02962	.18383	5.43966	.20194	4.95201	35
26	.14826	6.74483	.16615	6.01878	.18414	5.43077	.20224	4.94460	34
27	.14856	6.73133	.16645	6.00797	.18444	5.42192	.20254	4.93721	33
28	.14886	6.71789	.16674	5.99720	.18474	5.41309	.20285	4.92984	32
29	.14915	6.70450	.16704	5.98646	.18504	5.40429	.20315	4.92249	31
30	.14945	6.69116	.16734	5.97576	.18534	5.39552	.20345	4.91516	30
31	.14975	6.67787	.16764	5.96510	.18564	5.38677	.20376	4.90785	29
32	.15005	6.66463	.16794	5.95448	.18594	5.37805	.20406	4.90056	28
33	.15034	6.65144	.16824	5.94390	.18624	5.36936	.20436	4.89330	27
34	.15064	6.63831	.16854	5.93335	.18654	5.36070	.20466	4.83605	26
35	.15094	6.62523	.16884	5.92283	.18684	5.35206	.20497	4.87882	25
36	.15124	6.61219	.16914	5.91235	.18714	5.34345	.20527	4.87162	24
37	.15153	6.59921	.16944	5.90191	.18745	5.33487	.20557	4.86444	23
38	.15183	6.58627	.16974	5.89151	.18775	5.32631	.20588	4.85727	22
39	.15213	6.57339	.17004	5.88114	.18805	5.31778	.20618	4.85013	21
40	.15243	6.56055	.17033	5.87080	.18835	5.30928	.20648	4.84300	20
41	.15272	6.54777	.17063	5.86051	.18865	5.30080	.20679	4.83590	19
42	.15302	6.53503	.17093	5.85024	.18895	5.29235	.20709	4.82882	18
43	.15332	6.52234	.17123	5.84001	.18925	5.28393	.20739	4.82175	17
44	.15362	6.50970	.17153	5.82982	.18955	5.27553	.20770	4.81471	16
45	.15391	6.49710	.17183	5.81966	.18986	5.26715	.20800	4.80769	15
46	.15421	6.48456	.17213	5.80953	.19016	5.25880	.20830	4.80068	14
47	.15451	6.47206	.17243	5.79944	.19046	5.25048	.20861	4.79370	13
48	.15481	6.45961	.17273	5.78938	.19076	5.24218	.20891	4.78673	12
49	.15511	6.44720	.17303	5.77936	.19106	5.23391	.20921	4.77978	11
50	.15540	6.43484	.17333	5.76937	.19136	5.22566	.20952	4.77286	10
51	.15570	6.42253	.17363	5.75941	.19166	5.21744	.20982	4.76595	9
52	.15600	6.41026	.17393	5.74949	.19197	5.20925	.21013	4.75906	8
53	.15630	6.39804	.17423	5.73960	.19227	5.20107	.21043	4.75219	7
54	.15660	6.38587	.17453	5.72974	.19257	5.19293	.21073	4.74534	6
55	.15689	6.37374	.17483	5.71992	.19287	5.18480	.21104	4.73851	5
56	.15719	6.36165	.17513	5.71013	.19317	5.17671	.21134	4.73170	4
57	.15749	6.34961	.17543	5.70037	.19347	5.16863	.21164	4.72490	3
58	.15779	6.33761	.17573	5.69064	.19378	5.16058	.21195	4.71813	2
59	.15809	6.32566	.17603	5.68094	.19408	5.15256	.21225	4.71137	1
60	.15838	6.31375	.17633	5.67128	.19438	5.14455	.21256	4.70463	0
′	Co-tan. 81°	Tan. 81°	Co-tan. 80°	Tan. 80°	Co-tan. 79°	Tan. 79°	Co-tan. 78°	Tan. 78°	′

′	12° Tan.	12° Co-tan.	13° Tan.	13° Co-tan.	14° Tan.	14° Co-tan.	15° Tan.	15° Co-tan.	′
0	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	60
1	.21286	4.69791	.23117	4.32573	.24964	4.00582	.26826	3.72771	59
2	.21316	4.69121	.23148	4.32001	.24995	4.00086	.26857	3.72338	58
3	.21347	4.68452	.23179	4.31430	.25026	3.99592	.26888	3.71907	57
4	.21377	4.67786	.23209	4.30860	.25056	3.99099	.26920	3.71476	56
5	.21408	4.67121	.23240	4.30291	.25087	3.98607	.26951	3.71046	55
6	.21438	4.66458	.23271	4.29724	.25118	3.98117	.26982	3.70616	54
7	.21469	4.65797	.23301	4.29159	.25149	3.97627	.27013	3.70188	53
8	.21499	4.65138	.23332	4.28595	.25180	3.97139	.27044	3.69761	52
9	.21529	4.64480	.23363	4.28032	.25211	3.96651	.27076	3.69335	51
10	.21560	4.63825	.23393	4.27471	.25242	3.96165	.27107	3.68909	50
11	.21590	4.63171	.23424	4.26911	.25273	3.95680	.27138	3.68485	49
12	.21621	4.62518	.23455	4.26352	.25304	3.95196	.27169	3.68061	48
13	.21651	4.61868	.23485	4.25795	.25335	3.94713	.27201	3.67638	47
14	.21682	4.61219	.23516	4.25239	.25366	3.94232	.27232	3.67217	46
15	.21712	4.60572	.23547	4.24685	.25397	3.93751	.27263	3.66796	45
16	.21743	4.59927	.23578	4.24132	.25428	3.93271	.27294	3.66376	44
17	.21773	4.59283	.23608	4.23580	.25459	3.92793	.27326	3.65957	43
18	.21804	4.58641	.23639	4.23030	.25490	3.92316	.27357	3.65538	42
19	.21834	4.58001	.23670	4.22481	.25521	3.91839	.27388	3.65121	41
20	.21864	4.57363	.23700	4.21933	.25552	3.91364	.27419	3.64705	40
21	.21895	4.56726	.23731	4.21387	.25583	3.90890	.27451	3.64289	39
22	.21925	4.56091	.23762	4.20842	.25614	3.90417	.27482	3.63874	38
23	.21956	4.55458	.23793	4.20298	.25645	3.89945	.27513	3.63461	37
24	.21986	4.54826	.23823	4.19756	.25676	3.89474	.27545	3.63048	36
25	.22017	4.54196	.23854	4.19215	.25707	3.89004	.27576	3.62636	35
26	.22047	4.53568	.23885	4.18675	.25738	3.88536	.27607	3.62224	34
27	.22078	4.52941	.23916	4.18137	.25769	3.88068	.27638	3.61814	33
28	.22108	4.52316	.23946	4.17600	.25800	3.87601	.27670	3.61405	32
29	.22139	4.51693	.23977	4.17064	.25831	3.87136	.27701	3.60996	31
30	.22169	4.51071	.24008	4.16530	.25862	3.86671	.27732	3.60588	30
31	.22200	4.50451	.24039	4.15997	.25893	3.86208	.27764	3.60181	29
32	.22231	4.49832	.24069	4.15465	.25924	3.85745	.27795	3.59775	28
33	.22261	4.49215	.24100	4.14934	.25955	3.85284	.27826	3.59370	27
34	.22292	4.48600	.24131	4.14405	.25986	3.84824	.27858	3.58966	26
35	.22322	4.47986	.24162	4.13877	.26017	3.84364	.27889	3.58562	25
36	.22353	4.47374	.24193	4.13350	.26048	3.83906	.27920	3.58160	24
37	.22383	4.46764	.24223	4.12825	.26079	3.83449	.27952	3.57758	23
38	.22414	4.46155	.24254	4.12301	.26110	3.82992	.27983	3.57357	22
39	.22444	4.45548	.24285	4.11778	.26141	3.82537	.28015	3.56957	21
40	.22475	4.44942	.24316	4.11256	.26172	3.82083	.28046	3.56557	20
41	.22505	4.44338	.24347	4.10736	.26203	3.81630	.28077	3.56159	19
42	.22536	4.43735	.24377	4.10216	.26235	3.81177	.28109	3.55761	18
43	.22567	4.43134	.24408	4.09699	.26266	3.80726	.28140	3.55364	17
44	.22597	4.42534	.24439	4.09182	.26297	3.80276	.28172	3.54968	16
45	.22628	4.41936	.24470	4.08666	.26328	3.79827	.28203	3.54573	15
46	.22658	4.41340	.24501	4.08152	.26359	3.79378	.28234	3.54179	14
47	.22689	4.40745	.24532	4.07639	.26390	3.78931	.28266	3.53785	13
48	.22719	4.40152	.24562	4.07127	.26421	3.78485	.28297	3.53393	12
49	.22750	4.39560	.24593	4.06616	.26452	3.78040	.28329	3.53001	11
50	.22781	4.38969	.24624	4.06107	.26483	3.77595	.28360	3.52609	10
51	.22811	4.38381	.24655	4.05599	.26515	3.77152	.28391	3.52219	9
52	.22842	4.37793	.24686	4.05092	.26546	3.76709	.28423	3.51829	8
53	.22872	4.37207	.24717	4.04586	.26577	3.76268	.28454	3.51441	7
54	.22903	4.36623	.24747	4.04081	.26608	3.75828	.28486	3.51053	6
55	.22934	4.36040	.24778	4.03578	.26639	3.75388	.28517	3.50666	5
56	.22964	4.35459	.24809	4.03075	.26670	3.74950	.28549	3.50279	4
57	.22995	4.34879	.24840	4.02574	.26701	3.74512	.28580	3.49894	3
58	.23026	4.34300	.24871	4.02074	.26733	3.74075	.28612	3.49509	2
59	.23056	4.33723	.24902	4.01576	.26764	3.73640	.28643	3.49125	1
60	.23087	4.33148	.24933	4.01078	.26795	3.73205	.28675	3.48741	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	77°		76°		75°		74°		

′	16° Tan.	16° Co-tan.	17° Tan.	17° Co-tan.	18° Tan.	18° Co-tan.	19° Tan.	19° Co-tan.	′
0	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35019	2.85555	42
19	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.29337	3.40869	.31242	3.20079	.33160	3.01489	.35117	2.84758	39
22	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.30097	3.32264	.32010	3.12400	.33945	2.94590	.35904	2.78523	15
46	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Co-tan. 73°	Tan. 73°	Co-tan. 72°	Tan. 72°	Co-tan. 71°	Tan. 71°	Co-tan. 70°	Tan. 70°	′

	20°		21°		22°		23°		
′	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	′
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	39
22	.37124	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43239	2.31271	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38862	.43932	2.27626	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	69°		68°		67°		66°		

′	24° Tan.	24° Co-tan.	25° Tan.	25° Co-tan.	26° Tan.	26° Co-tan.	27° Tan.	27° Co-tan.	
0	.44523	2.24604	.46631	2.14451	.48773	2.05030	.50953	1.96261	60
1	.44558	2.24428	.46666	2.14288	.48809	2.04879	.50989	1.96120	59
2	.44593	2.24252	.46702	2.14125	.48845	2.04728	.51026	1.95979	58
3	.44627	2.24077	.46737	2.13963	.48881	2.04577	.51063	1.95838	57
4	.44662	2.23902	.46772	2.13801	.48917	2.04426	.51099	1.95698	56
5	.44697	2.23727	.46808	2.13639	.48953	2.04276	.51136	1.95557	55
6	.44732	2.23553	.46843	2.13477	.48989	2.04125	.51173	1.95417	54
7	.44767	2.23378	.46879	2.13316	.49026	2.03975	.51209	1.95277	53
8	.44802	2.23204	.46914	2.13154	.49062	2.03825	.51246	1.95137	52
9	.44837	2.23030	.46950	2.12993	.49098	2.03675	.51283	1.94997	51
10	.44872	2.22857	.46985	2.12832	.49134	2.03526	.51319	1.94858	50
11	.44907	2.22683	.47021	2.12671	.49170	2.03376	.51356	1.94718	49
12	.44942	2.22510	.47056	2.12511	.49206	2.03227	.51393	1.94579	48
13	.44977	2.22337	.47092	2.12350	.49242	2.03078	.51430	1.94440	47
14	.45012	2.22164	.47128	2.12190	.49278	2.02929	.51467	1.94301	46
15	.45047	2.21992	.47163	2.12030	.49315	2.02780	.51503	1.94162	45
16	.45082	2.21819	.47199	2.11871	.49351	2.02631	.51540	1.94023	44
17	.45117	2.21647	.47234	2.11711	.49387	2.02483	.51577	1.93885	43
18	.45152	2.21475	.47270	2.11552	.49423	2.02335	.51614	1.93746	42
19	.45187	2.21304	.47305	2.11392	.49459	2.02187	.51651	1.93608	41
20	.45222	2.21132	.47341	2.11233	.49495	2.02039	.51688	1.93470	40
21	.45257	2.20961	.47377	2.11075	.49532	2.01891	.51724	1.93332	39
22	.45292	2.20790	.47412	2.10916	.49568	2.01743	.51761	1.93195	38
23	.45327	2.20619	.47448	2.10758	.49604	2.01596	.51798	1.93057	37
24	.45362	2.20449	.47483	2.10600	.49640	2.01449	.51835	1.92920	36
25	.45397	2.20278	.47519	2.10442	.49677	2.01302	.51872	1.92782	35
26	.45432	2.20108	.47555	2.10284	.49713	2.01155	.51909	1.92645	34
27	.45467	2.19938	.47590	2.10126	.49749	2.01008	.51946	1.92508	33
28	.45502	2.19769	.47626	2.09969	.49786	2.00862	.51983	1.92371	32
29	.45537	2.19599	.47662	2.09811	.49822	2.00715	.52020	1.92235	31
30	.45573	2.19430	.47698	2.09654	.49858	2.00569	.52057	1.92098	30
31	.45608	2.19261	.47733	2.09498	.49894	2.00423	.52094	1.91962	29
32	.45643	2.19092	.47769	2.09341	.49931	2.00277	.52131	1.91826	28
33	.45678	2.18923	.47805	2.09184	.49967	2.00131	.52168	1.91690	27
34	.45713	2.18755	.47840	2.09028	.50004	1.99986	.52205	1.91554	26
35	.45748	2.18587	.47876	2.08872	.50040	1.99841	.52242	1.91418	25
36	.45784	2.18419	.47912	2.08716	.50076	1.99695	.52279	1.91282	24
37	.45819	2.18251	.47948	2.08560	.50113	1.99550	.52316	1.91147	23
38	.45854	2.18084	.47984	2.08405	.50149	1.99406	.52353	1.91012	22
39	.45889	2.17916	.48019	2.08250	.50185	1.99261	.52390	1.90876	21
40	.45924	2.17749	.48055	2.08094	.50222	1.99116	.52427	1.90741	20
41	.45960	2.17582	.48091	2.07939	.50258	1.98972	.52464	1.90607	19
42	.45995	2.17416	.48127	2.07785	.50295	1.98828	.52501	1.90472	18
43	.46030	2.17249	.48163	2.07630	.50331	1.98684	.52538	1.90337	17
44	.46065	2.17083	.48198	2.07476	.50368	1.98540	.52575	1.90203	16
45	.46101	2.16917	.48234	2.07321	.50404	1.98396	.52613	1.90069	15
46	.46136	2.16751	.48270	2.07167	.50441	1.98253	.52650	1.89935	14
47	.46171	2.16585	.48306	2.07014	.50477	1.98110	.52687	1.89801	13
48	.46206	2.16420	.48342	2.06860	.50514	1.97966	.52724	1.89667	12
49	.46242	2.16255	.48378	2.06706	.50550	1.97823	.52761	1.89533	11
50	.46277	2.16090	.48414	2.06553	.50587	1.97680	.52798	1.89400	10
51	.46312	2.15925	.48450	2.06400	.50623	1.97538	.52836	1.89266	9
52	.46348	2.15760	.48486	2.06247	.50660	1.97395	.52873	1.89133	8
53	.46383	2.15596	.48521	2.06094	.50696	1.97253	.52910	1.89000	7
54	.46418	2.15432	.48557	2.05942	.50733	1.97111	.52947	1.88867	6
55	.46454	2.15268	.48593	2.05790	.50769	1.96969	.52984	1.88734	5
56	.46489	2.15104	.48629	2.05637	.50806	1.96827	.53022	1.88602	4
57	.46525	2.14940	.48665	2.05485	.50843	1.96685	.53059	1.88469	3
58	.46560	2.14777	.48701	2.05333	.50879	1.96544	.53096	1.88337	2
59	.46595	2.14614	.48737	2.05182	.50916	1.96402	.53134	1.88205	1
60	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	0
′	65° Co-tan.	65° Tan.	64° Co-tan.	64° Tan.	63° Co-tan.	63° Tan.	62° Co-tan.	62° Tan.	′

	28°		29°		30°		31°		
	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	
0	.53171	1.88073	.55431	1.80405	.57735	1.73205	.60086	1.66428	60
1	.53208	1.87941	.55469	1.80281	.57774	1.73089	.60126	1.66318	59
2	.53246	1.87809	.55507	1.80158	.57813	1.72973	.60165	1..6209	58
3	.53283	1.87677	.55545	1.80034	.57851	1.72857	.60205	1.66099	57
4	.53320	1.87546	.55583	1.79911	.57890	1.72741	.60245	1.65990	56
5	.53358	1.87415	.55621	1.79788	.57929	1.72625	.60284	1.65881	55
6	.53395	1.87283	.55659	1.79665	.57968	1.72509	.60324	1.65772	54
7	.53432	1.87152	.55697	1.79542	.58007	1.72393	.60364	1.65663	53
8	.53470	1.87021	.55736	1.79419	.58046	1.72278	.60403	1.65534	52
9	.53507	1.86891	.55774	1.79296	.58085	1.72163	.60443	1.65445	51
10	.53545	1.86760	.55812	1.79174	.58124	1.72047	.60483	1.65337	50
11	.53582	1.86630	.55850	1.79051	.58162	1.71932	.60522	1.65228	49
12	.53620	1.86499	.55888	1.78929	.58201	1.71817	.60562	1.65120	48
13	.53657	1.86369	.55926	1.78807	.58240	1.71702	.60602	1.65011	47
14	.53694	1.86239	.55964	1.78685	.58279	1.71588	.60642	1.64903	46
15	.53732	1.86109	.56003	1.78563	.58318	1.71473	.60681	1.64795	45
16	.53769	1.85979	.56041	1.78441	.58357	1.71358	.60721	1.64687	44
17	.53807	1.85850	.56079	1.78319	.58396	1.71244	.60761	1.64579	43
18	.53844	1.85720	.56117	1.78198	.58435	1.71129	.60801	1.64471	42
19	.53882	1.85591	.56156	1.78077	.58474	1.71015	.60841	1.64363	41
20	.53920	1.85462	.56194	1.77955	.58513	1.70901	.60881	1.64256	40
21	.53957	1.85333	.56232	1.77834	.58552	1.70787	.60921	1.64148	39
22	.53995	1.85204	.56270	1.77713	.58591	1.70673	.60960	1.64041	38
23	.54032	1.85075	.56309	1.77592	.58631	1.70560	.61000	1.63934	37
24	.54070	1.84946	.56347	1.77471	.58670	1.70446	.61040	1.63826	36
25	.54107	1.84818	.56385	1.77351	.58709	1.70332	.61080	1.63719	35
26	.54145	1.84689	.56424	1.77230	.58748	1.70219	.61120	1.63612	34
27	.54183	1.84561	.56462	1.77110	.58787	1.70106	.61160	1.63505	33
28	.54220	1.84433	.56500	1.76990	.58826	1.69992	.61200	1.63398	32
29	.54258	1.84305	.56539	1.76869	.58865	1.69879	.61240	1.63292	31
30	.54296	1.84177	.56577	1.76749	.58904	1.69766	.61280	1.63185	30
31	.54333	1.84049	.56616	1.76630	.58944	1.69653	.61320	1.63079	29
32	.54371	1.83922	.56654	1.76510	.58983	1.69541	.61360	1.62972	28
33	.54409	1.83794	.56693	1.76390	.59022	1.69428	.61400	1.62866	27
34	.54446	1.83667	.56731	1.76271	.59061	1.69316	.61440	1.62760	26
35	.54484	1.83540	.56769	1.76151	.59101	1.69203	.61480	1.62654	25
36	.54522	1.83413	.56808	1.76032	.59140	1.69091	.61520	1.62548	24
37	.54560	1.83286	.56846	1.75913	.59179	1.68979	.61561	1.62442	23
38	.54597	1.83159	.56885	1.75794	.59218	1.68866	.61601	1.62336	22
39	.54635	1.83033	.56923	1.75675	.59258	1.68754	.61641	1.62230	21
40	.54673	1.82906	.56962	1.75556	.59297	1.68643	.61681	1.62125	20
41	.54711	1.82780	.57000	1.75437	.59336	1.68531	.61721	1.62019	19
42	.54748	1.82654	.57039	1.75319	.59376	1.68419	.61761	1.61914	18
43	.54786	1.82528	.57078	1.75200	.59415	1.68308	.61801	1.61808	17
44	.54824	1.82402	.57116	1.75082	.59454	1.68196	.61842	1.61703	16
45	.54862	1.82276	.57155	1.74964	.59494	1.68085	.61882	1.61598	15
46	.54900	1.82150	.57193	1.74846	.59533	1.67974	.61922	1.61493	14
47	.54938	1.82025	.57232	1.74728	.59573	1.67863	.61962	1.61388	13
48	.54975	1.81899	.57271	1.74610	.59612	1.67752	.62003	1.61283	12
49	.55013	1.81774	.57309	1.74492	.59651	1.67641	.62043	1.61179	11
50	.55051	1.81649	.57348	1.74375	.59691	1.67530	.62083	1.61074	10
51	.55089	1.81524	.57386	1.74257	.59730	1.67419	.62124	1.60970	9
52	.55127	1.81399	.57425	1.74140	.59770	1.67309	.62164	1.60865	8
53	.55165	1.81274	.57464	1.74022	.59809	1.67198	.62204	1.60761	7
54	.55203	1.81150	.57503	1.73905	.59849	1.67088	.62245	1.60657	6
55	.55241	1.81025	.57541	1.73788	.59888	1.66978	.62285	1.60553	5
56	.55279	1.80901	.57580	1.73671	.59928	1.66867	.62325	1.60449	4
57	.55317	1.80777	.57619	1.73555	.59967	1.66757	.62366	1.60345	3
58	.55355	1.80653	.57657	1.73438	.60007	1.66647	.62406	1.60241	2
59	.55393	1.80529	.57696	1.73321	.60046	1.66538	.62446	1.60137	1
60	.55431	1.80405	.57735	1.73205	.60086	1.66428	.62487	1.60033	0
	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	
	61°		60°		59°		58°		

′	32° Tan.	32° Co-tan.	33° Tan.	33° Co-tan.	34° Tan.	34° Co-tan.	35° Tan.	35° Co-tan.	′
0	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	60
1	.62527	1.59930	.64982	1.53888	.67493	1.48163	.70064	1.42726	59
2	.62568	1.59826	.65023	1.53791	.67536	1.48070	.70107	1.42638	58
3	.62608	1.59723	.65065	1.53693	.67578	1.47977	.70151	1.42550	57
4	.62649	1.59620	.65106	1.53595	.67620	1.47885	.70194	1.42462	56
5	.62689	1.59517	.65148	1.53497	.67663	1.47792	.70238	1.42374	55
6	.62730	1.59414	.65189	1.53400	.67705	1.47699	.70281	1.42286	54
7	.62770	1.59311	.65231	1.53302	.67748	1.47607	.70325	1.42198	53
8	.62811	1.59208	.65272	1.53205	.67790	1.47514	.70368	1.42110	52
9	.62852	1.59105	.65314	1.53107	.67832	1.47422	.70412	1.42022	51
10	.62892	1.59002	.65355	1.53010	.67875	1.47330	.70455	1.41934	50
11	.62933	1.58900	.65397	1.52913	.67917	1.47238	.70499	1.41847	49
12	.62973	1.58797	.65438	1.52816	.67960	1.47146	.70542	1.41759	48
13	.63014	1.58695	.65480	1.52719	.68002	1.47053	.70586	1.41672	47
14	.63055	1.58593	.65521	1.52622	.68045	1.46962	.70629	1.41584	46
15	.63095	1.58490	.65563	1.52525	.68088	1.46870	.70673	1.41497	45
16	.63136	1.58388	.65604	1.52429	.68130	1.46778	.70717	1.41409	44
17	.63177	1.58286	.65646	1.52332	.68173	1.46686	.70760	1.41322	43
18	.63217	1.58184	.65688	1.52235	.68215	1.46595	.70804	1.41235	42
19	.63258	1.58083	.65729	1.52139	.68258	1.46503	.70848	1.41148	41
20	.63299	1.57981	.65771	1.52043	.68301	1.46411	.70891	1.41061	40
21	.63340	1.57879	.65813	1.51946	.68343	1.46320	.70935	1.40974	39
22	.63380	1.57778	.65854	1.51850	.68386	1.46229	.70979	1.40887	38
23	.63421	1.57676	.65896	1.51754	.68429	1.46137	.71023	1.40800	37
24	.63462	1.57575	.65938	1.51658	.68471	1.46046	.71066	1.40714	36
25	.63503	1.57474	.65980	1.51562	.68514	1.45955	.71110	1.40627	35
26	.63544	1.57372	.66021	1.51466	.68557	1.45864	.71154	1.40540	34
27	.63584	1.57271	.66063	1.51370	.68600	1.45773	.71198	1.40454	33
28	.63625	1.57170	.66105	1.51275	.68642	1.45682	.71242	1.40367	32
29	.63666	1.57069	.66147	1.51179	.68685	1.45592	.71285	1.40281	31
30	.63707	1.56969	.66189	1.51084	.68728	1.45501	.71329	1.40195	30
31	.63748	1.56868	.66230	1.50988	.68771	1.45410	.71373	1.40109	29
32	.63789	1.56767	.66272	1.50893	.68814	1.45320	.71417	1.40022	28
33	.63830	1.56667	.66314	1.50797	.68857	1.45229	.71461	1.39936	27
34	.63871	1.56566	.66356	1.50702	.68900	1.45139	.71505	1.39850	26
35	.63912	1.56466	.66398	1.50607	.68942	1.45049	.71549	1.39764	25
36	.63953	1.56366	.66440	1.50512	.68985	1.44958	.71593	1.39679	24
37	.63994	1.56265	.66482	1.50417	.69028	1.44868	.71637	1.39593	23
38	.64035	1.56165	.66524	1.50322	.69071	1.44778	.71681	1.39507	22
39	.64076	1.56065	.66566	1.50228	.69114	1.44688	.71725	1.39421	21
40	.64117	1.55966	.66608	1.50133	.69157	1.44598	.71769	1.39336	20
41	.64158	1.55866	.66650	1.50038	.69200	1.44508	.71813	1.39250	19
42	.64199	1.55766	.66692	1.49944	.69243	1.44418	.71857	1.39165	18
43	.64240	1.55666	.66734	1.49849	.69286	1.44329	.71901	1.39079	17
44	.64281	1.55567	.66776	1.49755	.69329	1.44239	.71946	1.38994	16
45	.64322	1.55467	.66818	1.49661	.69372	1.44149	.71990	1.38909	15
46	.64363	1.55368	.66860	1.49566	.69416	1.44060	.72034	1.38824	14
47	.64404	1.55269	.66902	1.49472	.69459	1.43970	.72078	1.38738	13
48	.64446	1.55170	.66944	1.49378	.69502	1.43881	.72122	1.38653	12
49	.64487	1.55071	.66986	1.49284	.69545	1.43792	.72166	1.38568	11
50	.64528	1.54972	.67028	1.49190	.69588	1.43703	.72211	1.38484	10
51	.64569	1.54873	.67071	1.49097	.69631	1.43614	.72255	1.38399	9
52	.64610	1.54774	.67113	1.49003	.69675	1.43525	.72299	1.38314	8
53	.64652	1.54675	.67155	1.48909	.69718	1.43436	.72344	1.38229	7
54	.64693	1.54576	.67197	1.48816	.69761	1.43347	.72388	1.38145	6
55	.64734	1.54478	.67239	1.48722	.69804	1.43258	.72432	1.38060	5
56	.64775	1.54379	.67282	1.48629	.69847	1.43169	.72477	1.37976	4
57	.64817	1.54281	.67324	1.48536	.69891	1.43080	.72521	1.37891	3
58	.64858	1.54183	.67366	1.48442	.69934	1.42992	.72565	1.37807	2
59	.64899	1.54085	.67409	1.48349	.69977	1.42903	.72610	1.37722	1
60	.64941	1.53986	.67451	1.48256	.70021	1.42815	.72654	1.37638	0
′	Co-tan. 57°	Tan. 57°	Co-tan. 56°	Tan. 56°	Co-tan. 55°	Tan. 55°	Co-tan. 54°	Tan. 54°	′

′	36° Tan.	36° Co-tan.	37° Tan.	37° Co-tan.	38° Tan.	38° Co-tan.	39° Tan.	39° Co-tan.	′
0	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	44
17	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.73457	1.36133	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan	Tan.	Co-tan.	Tan	′
	53°		52°		51°		50°		

′	40°		41°		42°		43°		′
	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	33
28	.85307	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	49°		48°		47°		46°		

′	44°		′	′	44°		′	′	44°		′
′	Tan.	Co-tan.	′	′	Tan.	Co-tan.	′	′	Tan.	Co-tan.	′
0	.96569	1.03553	60	21	.97756	1.02295	39	41	.98901	1.01112	19
1	.96625	1.03493	59	22	.97813	1.02236	38	42	.98958	1.01053	18
2	.96681	1.03433	58	23	.97870	1.02176	37	43	.99016	1.00994	17
3	.96738	1.03372	57	24	.97927	1.02117	36	44	.99073	1.00935	16
4	.96794	1.03312	56	25	.97984	1.02057	35	45	.99131	1.00876	15
5	.96850	1.03252	55	26	.98041	1.01998	34	46	.99189	1.00818	14
6	.96907	1.03192	54	27	.98098	1.01939	33	47	.99247	1.00759	13
7	.96963	1.03132	53	28	.98155	1.01879	32	48	.99304	1.00701	12
8	.97020	1.03072	52	29	.98213	1.01820	31	49	.99362	1.00642	11
9	.97076	1.03012	51	30	.98270	1.01761	30	50	.99420	1.00583	10
10	.97133	1.02952	50	31	.98327	1.01702	29	51	.99478	1.00525	9
11	.97189	1.02892	49	32	.98384	1.01642	28	52	.99536	1.00467	8
12	.97246	1.02832	48	33	.98441	1.01583	27	53	.99594	1.00408	7
13	.97302	1.02772	47	34	.98499	1.01524	26	54	.99652	1.00350	6
14	.97359	1.02713	46	35	.98556	1.01465	25	55	.99710	1.00291	5
15	.97416	1.02653	45	36	.98613	1.01406	24	56	.99768	1.00233	4
16	.97472	1.02593	44	37	.98671	1.01347	23	57	.99826	1.00175	3
17	.97529	1.02533	43	38	.98728	1.01288	22	58	.99884	1.00116	2
18	.97586	1.02474	42	39	.98786	1.01229	21	59	.99942	1.00058	1
19	.97643	1.02414	41	40	.98843	1.01170	20	60	1	1	0
20	.97700	1.02355	40								
′	Co-tan.	Tan.	′	′	Co-tan.	Tan.	′	′	Co-tan.	Tan.	′
	45°				45°				45°		

NATURAL SINES AND COSINES

′	0°		′	′	0°		′	′	0°		′
′	Sine	Cosine	′	′	Sine	Cosine	′	′	Sine	Cosine	′
0	.00000	1	60	21	.00611	.99998	39	41	.01193	.99993	19
1	.00029	1	59	22	.00640	.99998	38	42	.01222	.99993	18
2	.00058	1	58	23	.00669	.99998	37	43	.01251	.99992	17
3	.00087	1	57	24	.00698	.99998	36	44	.01280	.99992	16
4	.00116	1	56	25	.00727	.99997	35	45	.01309	.99991	15
5	.00145	1	55	26	.00756	.99997	34	46	.01338	.99991	14
6	.00175	1	54	27	.00785	.99997	33	47	.01367	.99991	13
7	.00204	1	53	28	.00814	.99997	32	48	.01396	.99990	12
8	.00233	1	52	29	.00844	.99996	31	49	.01425	.99990	11
9	.00262	1	51	30	.00873	.99996	30	50	.01454	.99989	10
10	.00291	1	50	31	.00902	.99996	29	51	.01483	.99989	9
11	.00320	.99999	49	32	.00931	.99996	28	52	.01513	.99989	8
12	.00349	.99999	48	33	.00960	.99995	27	53	.01542	.99988	7
13	.00378	.99999	47	34	.00989	.99995	26	54	.01571	.99988	6
14	.00407	.99999	46	35	.01018	.99995	25	55	.01600	.99987	5
15	.00436	.99999	45	36	.01047	.99995	24	56	.01629	.99987	4
16	.00465	.99999	44	37	.01076	.99994	23	57	.01658	.99986	3
17	.00495	.99999	43	38	.01105	.99994	22	58	.01687	.99986	2
18	.00524	.99999	42	39	.01134	.99994	21	59	.01716	.99985	1
19	.00553	.99998	41	40	.01164	.99993	20	60	.01745	.99985	0
20	.00582	.99998	40								
′	Cosine	Sine	′	′	Cosine	Sine	′	′	Cosine	Sine	′
	89°				89°				89°		

′	1° Sine	1° Cosine	2° Sine	2° Cosine	3° Sine	3° Cosine	4° Sine	4° Cosine	′
0	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosine 88°	Sine 88°	Cosine 87°	Sine 87°	Cosine 86°	Sine 86°	Cosine 85°	Sine 85°	′

′	5° Sine	5° Cosine	6° Sine	6° Cosine	7° Sine	7° Cosine	8° Sine	8° Cosine	′
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	84°		83°		82°		81°		

′	9° Sine	9° Cosine	10° Sine	10° Cosine	11° Sine	11° Cosine	12° Sine	12° Cosine	′
0	.15643	.98769	.17365	.98481	.19081	.98163	.20791	.97815	60
1	.15672	.98764	.17393	.98476	.19109	.98157	.20820	.97809	59
2	.15701	.98760	.17422	.98471	.19138	.98152	.20848	.97803	58
3	.15730	.98755	.17451	.98466	.19167	.98146	.20877	.97797	57
4	.15758	.98751	.17479	.98461	.19195	.98140	.20905	.97791	56
5	.15787	.98746	.17508	.98455	.19224	.98135	.20933	.97784	55
6	.15816	.98741	.17537	.98450	.19252	.98129	.20962	.97778	54
7	.15845	.98737	.17565	.98445	.19281	.98124	.20990	.97772	53
8	.15873	.98732	.17594	.98440	.19309	.98118	.21019	.97766	52
9	.15902	.98728	.17623	.98435	.19338	.98112	.21047	.97760	51
10	.15931	.98723	.17651	.98430	.19366	.98107	.21076	.97754	50
11	.15959	.98718	.17680	.98425	.19395	.98101	.21104	.97748	49
12	.15988	.98714	.17708	.98420	.19423	.98096	.21132	.97742	48
13	.16017	.98709	.17737	.98414	.19452	.98090	.21161	.97735	47
14	.16046	.98704	.17766	.98409	.19481	.98084	.21189	.97729	46
15	.16074	.98700	.17794	.98404	.19509	.98079	.21218	.97723	45
16	.16103	.98695	.17823	.98399	.19538	.98073	.21246	.97717	44
17	.16132	.98690	.17852	.98394	.19566	.98067	.21275	.97711	43
18	.16160	.98689	.17880	.98389	.19595	.98061	.21303	.97705	42
19	.16189	.98681	.17909	.98383	.19623	.98056	.21331	.97698	41
20	.16218	.98676	.17937	.98378	.19652	.98050	.21360	.97692	40
21	.16246	.98671	.17966	.98373	.19680	.98044	.21388	.97686	39
22	.16275	.98667	.17995	.98368	.19709	.98039	.21417	.97680	38
23	.16304	.98662	.18023	.98362	.19737	.98033	.21445	.97673	37
24	.16333	.98657	.18052	.98357	.19766	.98027	.21474	.97667	36
25	.16361	.98652	.18081	.98352	.19794	.98021	.21502	.97661	35
26	.16390	.98648	.18109	.98347	.19823	.98016	.21530	.97655	34
27	.16419	.98643	.18138	.98341	.19851	.98010	.21559	.97648	33
28	.16447	.98638	.18166	.98336	.19880	.98004	.21587	.97642	32
29	.16476	.98633	.18195	.98331	.19908	.97987	.21616	.97636	31
30	.16505	.98629	.18224	.98325	.19937	.97992	.21644	.97630	30
31	.16533	.98624	.18252	.98320	.19965	.97987	.21672	.97623	29
32	.16562	.98619	.18281	.98315	.19994	.97981	.21701	.97617	28
33	.16591	.98614	.18309	.98310	.20022	.97975	.21729	.97611	27
34	.16620	.98609	.18338	.98304	.20031	.97969	.21758	.97604	26
35	.16648	.98604	.18367	.98299	.20079	.97963	.21786	.97598	25
36	.16677	.98600	.18395	.98294	.20108	.97958	.21814	.97592	24
37	.16706	.98595	.18424	.98288	.20136	.97952	.21843	.97585	23
38	.16734	.98590	.18452	.98283	.20165	.97946	.21871	.97579	22
39	.16763	.98585	.18481	.98277	.20193	.97940	.21899	.97573	21
40	.16792	.98580	.18509	.98272	.20222	.97934	.21928	.97566	20
41	.16820	.98575	.18538	.98267	.20250	.97928	.21956	.97560	19
42	.16849	.98570	.18567	.98261	.20279	.97922	.21985	.97553	18
43	.16878	.98565	.18595	.98256	.20307	.97916	.22013	.97547	17
44	.16906	.98561	.18624	.98250	.20336	.97910	.22041	.97541	16
45	.16935	.98556	.18652	.98245	.20364	.97905	.22070	.97534	15
46	.16964	.98551	.18681	.98240	.20393	.97899	.22098	.97528	14
47	.16992	.98546	.18710	.98234	.20421	.97893	.22126	.97521	13
48	.17021	.98541	.18738	.98229	.20450	.97887	.22155	.97515	12
49	.17050	.98536	.18767	.98223	.20478	.97881	.22183	.97508	11
50	.17078	.98531	.18795	.98218	.20507	.97875	.22212	.97502	10
51	.17107	.98526	.18824	.98212	.20535	.97869	.22240	.97496	9
52	.17136	.98521	.18852	.98207	.20563	.97863	.22268	.97489	8
53	.17164	.98516	.18881	.98201	.20592	.97857	.22297	.97483	7
54	.17193	.98511	.18910	.98196	.20620	.97851	.22325	.97476	6
55	.17222	.98506	.18938	.98190	.20649	.97845	.22353	.97470	5
56	.17250	.98501	.18967	.98185	.20677	.97839	.22382	.97463	4
57	.17279	.98496	.18995	.98179	.20706	.97833	.22410	.97457	3
58	.17308	.98491	.19024	.98174	.20734	.97827	.22438	.97450	2
59	.17336	.98486	.19052	.98168	.20763	.97821	.22467	.97444	1
60	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	0
′	80° Cosine	80° Sine	79° Cosine	79° Sine	78° Cosine	78° Sine	77° Cosine	77° Sine	′

′	13° Sine	13° Cosine	14° Sine	14° Cosine	15° Sine	15° Cosine	16° Sine	16° Cosine	′
0	.22495	.97437	.24192	.97030	.25882	.96593	.27564	.96126	60
1	.22523	.97430	.24220	.97023	.25910	.96585	.27592	.96118	59
2	.22552	.97424	.24249	.97015	.25938	.96578	.27620	.96110	58
3	.22580	.97417	.24277	.97008	.25966	.96570	.27648	.96102	57
4	.22608	.97411	.24305	.97001	.25994	.96562	.27676	.96094	56
5	.22637	.97404	.24333	.96994	.26022	.96555	.27704	.96086	55
6	.22665	.97398	.24362	.96987	.26050	.96547	.27731	.96078	54
7	.22693	.97391	.24390	.96980	.26079	.96540	.27759	.96070	53
8	.22722	.97384	.24418	.96973	.26107	.96532	.27787	.96062	52
9	.22750	.97378	.24446	.96966	.26135	.96524	.27815	.96054	51
10	.22778	.97371	.24474	.96959	.26163	.96517	.27843	.96046	50
11	.22807	.97365	.24503	.96952	.26191	.96509	.27871	.96037	49
12	.22835	.97358	.24531	.96945	.26219	.96502	.27899	.96029	48
13	.22863	.97351	.24559	.96937	.26247	.96494	.27927	.96021	47
14	.22892	.97345	.24587	.96930	.26275	.96486	.27955	.96013	46
15	.22920	.97338	.24615	.96923	.26303	.96479	.27983	.96005	45
16	.22948	.97331	.24644	.96916	.26331	.96471	.28011	.95997	44
17	.22977	.97325	.24672	.96909	.26359	.96463	.28039	.95989	43
18	.23005	.97318	.24700	.96902	.26387	.96456	.28067	.95981	42
19	.23033	.97311	.24728	.96894	.26415	.96448	.28095	.95972	41
20	.23062	.97304	.24756	.96887	.26443	.96440	.28123	.95964	40
21	.23090	.97298	.24784	.96880	.26471	.96433	.28150	.95956	39
22	.23118	.97291	.24813	.96873	.26500	.96425	.28178	.95948	38
23	.23146	.97284	.24841	.96866	.26528	.96417	.28206	.95940	37
24	.23175	.97278	.24869	.96858	.26556	.96410	.28234	.95931	36
25	.23203	.97271	.24897	.96851	.26584	.96402	.28262	.95923	35
26	.23231	.97264	.24925	.96844	.26612	.96394	.28290	.95915	34
27	.23260	.97257	.24954	.96837	.26640	.96386	.28318	.95907	33
28	.23288	.97251	.24982	.96829	.26668	.96379	.28346	.95898	32
29	.23316	.97244	.25010	.96822	.26696	.96371	.28374	.95890	31
30	.23345	.97237	.25038	.96815	.26724	.96363	.28402	.95882	30
31	.23373	.97230	.25066	.96807	.26752	.96355	.28429	.95874	29
32	.23401	.97223	.25094	.96800	.26780	.96347	.28457	.95865	28
33	.23429	.97217	.25122	.96793	.26808	.96340	.28485	.95857	27
34	.23458	.97210	.25151	.96786	.26836	.96332	.28513	.95849	26
35	.23486	.97203	.25179	.96778	.26864	.96324	.28541	.95841	25
36	.23514	.97196	.25207	.96771	.26892	.96316	.28569	.95832	24
37	.23542	.97189	.25235	.96764	.26920	.96308	.28597	.95824	23
38	.23571	.97182	.25263	.96756	.26948	.96301	.28625	.95816	22
39	.23599	.97176	.25291	.96749	.26976	.96293	.28652	.95807	21
40	.23627	.97169	.25320	.96742	.27004	.96285	.28680	.95799	20
41	.23656	.97162	.25348	.96734	.27032	.96277	.28708	.95791	19
42	.23684	.97155	.25376	.96727	.27060	.96269	.28736	.95782	18
43	.23712	.97148	.25404	.96719	.27088	.96261	.28764	.95774	17
44	.23740	.97141	.25432	.96712	.27116	.96253	.28792	.95766	16
45	.23769	.97134	.25460	.96705	.27144	.96246	.28820	.95757	15
46	.23797	.97127	.25488	.96697	.27172	.96238	.28847	.95749	14
47	.23825	.97120	.25516	.96690	.27200	.96230	.28875	.95740	13
48	.23853	.97113	.25545	.96682	.27228	.96222	.28903	.95732	12
49	.23882	.97106	.25573	.96675	.27256	.96214	.28931	.95724	11
50	.23910	.97100	.25601	.96667	.27284	.96206	.28959	.95715	10
51	.23938	.97093	.25629	.96660	.27312	.96198	.28987	.95707	9
52	.23966	.97086	.25657	.96653	.27340	.96190	.29015	.95698	8
53	.23995	.97079	.25685	.96645	.27368	.96182	.29042	.95690	7
54	.24023	.97072	.25713	.96638	.27396	.96174	.29070	.95681	6
55	.24051	.97065	.25741	.96630	.27424	.96166	.29098	.95673	5
56	.24079	.97058	.25769	.96623	.27452	.96158	.29126	.95664	4
57	.24108	.97051	.25798	.96615	.27480	.96150	.29154	.95656	3
58	.24136	.97044	.25826	.96608	.27508	.96142	.29182	.95647	2
59	.24164	.97037	.25854	.96600	.27536	.96134	.29209	.95639	1
60	.24192	.97030	.25882	.96593	.27564	.96126	.29237	.95630	0
′	Cosine 76°	Sine 76°	Cosine 75°	Sine 75°	Cosine 74°	Sine 74°	Cosine 73°	Sine 73°	′

′	17° Sine	17° Cosine	18° Sine	18° Cosine	19° Sine	19° Cosine	20° Sine	20° Cosine	′
0	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	60
1	.29265	.95622	.30929	.95097	.32584	.94542	.34229	.93959	59
2	.29293	.95613	.30957	.95088	.32612	.94533	.34257	.93949	58
3	.29321	.95605	.30985	.95079	.32639	.94523	.34284	.93939	57
4	.29348	.95596	.31012	.95070	.32667	.94514	.34311	.93929	56
5	.29376	.95588	.31040	.95061	.32694	.94504	.34339	.93919	55
6	.29404	.95579	.31068	.95052	.32722	.94495	.34366	.93909	54
7	.29432	.95571	.31095	.95043	.32749	.94485	.34393	.93899	53
8	.29460	.95562	.31123	.95033	.32777	.94476	.34421	.93889	52
9	.29487	.95554	.31151	.95024	.32804	.94466	.34448	.93879	51
10	.29515	.95545	.31178	.95015	.32832	.94457	.34475	.93869	50
11	.29543	.95536	.31206	.95006	.32859	.94447	.34503	.93859	49
12	.29571	.95528	.31233	.94997	.32887	.94438	.34530	.93849	48
13	.29599	.95519	.31261	.94988	.32914	.94428	.34557	.93839	47
14	.29626	.95511	.31289	.94979	.32942	.94418	.34584	.93829	46
15	.29654	.95502	.31316	.94970	.32969	.94409	.34612	.93819	45
16	.29682	.95493	.31344	.94961	.32997	.94399	.34639	.93809	44
17	.29710	.95485	.31372	.94952	.33024	.94390	.34666	.93799	43
18	.29737	.95476	.31399	.94943	.33051	.94380	.34694	.93789	42
19	.29765	.95467	.31427	.94933	.33079	.94370	.34721	.93779	41
20	.29793	.95459	.31454	.94924	.33106	.94361	.34748	.93769	40
21	.29821	.95450	.31482	.94915	.33134	.94351	.34775	.93759	39
22	.29849	.95441	.31510	.94906	.33161	.94342	.34803	.93748	38
23	.29876	.95433	.31537	.94897	.33189	.94332	.34830	.93738	37
24	.29904	.95424	.31565	.94888	.33216	.94322	.34857	.93728	36
25	.29932	.95415	.31593	.94878	.33244	.94313	.34884	.93718	35
26	.29960	.95407	.31620	.94869	.33271	.94303	.34912	.93708	34
27	.29987	.95398	.31648	.94860	.33298	.94293	.34939	.93698	33
28	.30015	.95389	.31675	.94851	.33326	.94284	.34966	.93688	32
29	.30043	.95380	.31703	.94842	.33353	.94274	.34993	.93677	31
30	.30071	.95372	.31730	.94832	.33381	.94264	.35021	.93667	30
31	.30098	.95363	.31758	.94823	.33408	.94254	.35048	.93657	29
32	.30126	.95354	.31786	.94814	.33436	.94245	.35075	.93647	28
33	.30154	.95345	.31813	.94805	.33463	.94235	.35102	.93637	27
34	.30182	.95337	.31841	.94795	.33490	.94225	.35130	.93626	26
35	.30209	.95328	.31868	.94786	.33518	.94215	.35157	.93616	25
36	.30237	.95319	.31896	.94777	.33545	.94206	.35184	.93606	24
37	.30265	.95310	.31923	.94768	.33573	.94196	.35211	.93596	23
38	.30292	.95301	.31951	.94758	.33600	.94186	.35239	.93585	22
39	.30320	.95293	.31979	.94749	.33627	.94176	.35266	.93575	21
40	.30348	.95284	.32006	.94740	.33655	.94167	.35293	.93565	20
41	.30376	.95275	.32034	.94730	.33682	.94157	.35320	.93555	19
42	.30403	.95266	.32061	.94721	.33710	.94147	.35347	.93544	18
43	.30431	.95257	.32089	.94712	.33737	.94137	.35375	.93534	17
44	.30459	.95248	.32116	.94702	.33764	.94127	.35402	.93524	16
45	.30486	.95240	.32144	.94693	.33792	.94118	.35429	.93514	15
46	.30514	.95231	.32171	.94684	.33819	.94108	.35456	.93503	14
47	.30542	.95222	.32199	.94674	.33846	.94098	.35484	.93493	13
48	.30570	.95213	.32227	.94665	.33874	.94088	.35511	.93483	12
49	.30597	.95204	.32254	.94656	.33901	.94078	.35538	.93472	11
50	.30625	.95195	.32282	.94646	.33929	.94068	.35565	.93462	10
51	.30653	.95186	.32309	.94637	.33956	.94058	.35592	.93452	9
52	.30680	.95177	.32337	.94627	.33983	.94049	.35619	.93441	8
53	.30708	.95168	.32364	.94618	.34011	.94039	.35647	.93431	7
54	.30736	.95159	.32392	.94609	.34038	.94029	.35674	.93420	6
55	.30763	.95150	.32419	.94599	.34065	.94019	.35701	.93410	5
56	.30791	.95142	.32447	.94590	.34093	.94009	.35728	.93400	4
57	.30819	.95133	.32474	.94580	.34120	.93999	.35755	.93389	3
58	.30846	.95124	.32502	.94571	.34147	.93989	.35782	.93379	2
59	.30874	.95115	.32529	.94561	.34175	.93979	.35810	.93368	1
60	.30902	.95106	.32557	.94552	.34202	.93969	.35837	.93358	0
′	Cosine 72°	Sine 72°	Cosine 71°	Sine 71°	Cosine 70°	Sine 70°	Cosine 69°	Sine 69°	′

′	21° Sine	21° Cosine	22° Sine	22° Cosine	23° Sine	23° Cosine	24° Sine	24° Cosine	′
0	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	68° Cosine	68° Sine	67° Cosine	67° Sine	66° Cosine	66° Sine	65° Cosine	65° Sine	′

′	25° Sine	25° Cosine	26° Sine	26° Cosine	27° Sine	27° Cosine	28° Sine	28° Cosine	′
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	31
30	.43051	.90259	.44620	89493	.46175	.88701	.47716	.87882	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	9
52	.43628	.89981	45192	.89206	.46742	.88404	.48277	.87575	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	0
′	64° Cosine	64° Sine	63° Cosine	63° Sine	62° Cosine	62° Sine	61° Cosine	61° Sine	′

′	29° Sine	29° Cosine	30° Sine	30° Cosine	31° Sine	31° Cosine	32° Sine	32° Cosine	′
0	.48481	.87462	.50000	.86603	.51504	.85717	.52992	.84805	60
1	.48506	.87448	.50025	.86588	.51529	.85702	.53017	.84789	59
2	.48532	.87434	.50050	.86573	.51554	.85687	.53041	.84774	58
3	.48557	.87420	.50076	.86559	.51579	.85672	.53066	.84759	57
4	.48583	.87406	.50101	.86544	.51604	.85657	.53091	.84743	56
5	.48608	.87391	.50126	.86530	.51628	.85642	.53115	.84728	55
6	.48634	.87377	.50151	.86515	.51653	.85627	.53140	.84712	54
7	.48659	.87363	.50176	.86501	.51678	.85612	.53164	.84697	53
8	.48684	.87349	.50201	.86486	.51703	.85597	.53189	.84681	52
9	.48710	.87335	.50227	.86471	.51728	.85582	.53214	.84666	51
10	.48735	.87321	.50252	.86457	.51753	.85567	.53238	.84650	50
11	.48761	.87306	.50277	.86442	.51778	.85551	.53263	.84635	49
12	.48786	.87292	.50302	.86427	.51803	.85536	.53288	.84619	48
13	.48811	.87278	.50327	.86413	.51828	.85521	.53312	.84604	47
14	.48837	.87264	.50352	.86398	.51852	.85506	.53337	.84588	46
15	.48862	.87250	.50377	.86384	.51877	.85491	.53361	.84573	45
16	.48888	.87235	.50403	.86369	.51902	.85476	.53386	.84557	44
17	.48913	.87221	.50428	.86354	.51927	.85461	.53411	.84542	43
18	.48938	.87207	.50453	.86340	.51952	.85446	.53435	.84526	42
19	.48964	.87193	.50478	.86325	.51977	.85431	.53460	.84511	41
20	.48989	.87178	.50503	.86310	.52002	.85416	.53484	.84495	40
21	.49014	.87164	.50528	.86295	.52026	.85401	.53509	.84480	39
22	.49040	.87150	.50553	.86281	.52051	.85385	.53534	.84464	38
23	.49065	.87136	.50578	.86266	.52076	.85370	.53558	.84448	37
24	.49090	.87121	.50603	.86251	.52101	.85355	.53583	.84433	36
25	.49116	.87107	.50628	.86237	.52126	.85340	.53607	.84417	35
26	.49141	.87093	.50654	.86222	.52151	.85325	.53632	.84402	34
27	.49166	.87079	.50679	.86207	.52175	.85310	.53656	.84386	33
28	.49192	.87064	.50704	.86192	.52200	.85294	.53681	.84370	32
29	.49217	.87050	.50729	.86178	.52225	.85279	.53705	.84355	31
30	.49242	.87036	.50754	.86163	.52250	.85264	.53730	.84339	30
31	.49268	.87021	.50779	.86148	.52275	.85249	.53754	.84324	29
32	.49293	.87007	.50804	.86133	.52299	.85234	.53779	.84308	28
33	.49318	.86993	.50829	.86119	.52324	.85218	.53804	.84292	27
34	.49344	.86978	.50854	.86104	.52349	.85203	.53828	.84277	26
35	.49369	.86964	.50879	.86089	.52374	.85188	.53853	.84261	25
36	.49394	.86949	.50904	.86074	.52399	.85173	.53877	.84245	24
37	.49419	.86935	.50929	.86059	.52423	.85157	.53902	.84230	23
38	.49445	.86921	.50954	.86045	.52448	.85142	.53926	.84214	22
39	.49470	.86906	.50979	.86030	.52473	.85127	.53951	.84198	21
40	.49495	.86892	.51004	.86015	.52498	.85112	.53975	.84182	20
41	.49521	.86878	.51029	.86000	.52522	.85096	.54000	.84167	19
42	.49546	.86863	.51054	.85985	.52547	.85081	.54024	.84151	18
43	.49571	.86849	.51079	.85970	.52572	.85066	.54049	.84135	17
44	.49596	.86834	.51104	.85956	.52597	.85051	.54073	.84120	16
45	.49622	.86820	.51129	.85941	.52621	.85035	.54097	.84104	15
46	.49647	.86805	.51154	.85926	.52646	.85020	.54122	.84088	14
47	.49672	.86791	.51179	.85911	.52671	.85005	.54146	.84072	13
48	.49697	.86777	.51204	.85896	.52696	.84989	.54171	.84057	12
49	.49723	.86762	.51229	.85881	.52720	.84974	.54195	.84041	11
50	.49748	.86748	.51254	.85866	.52745	.84959	.54220	.84025	10
51	.49773	.86733	.51279	.85851	.52770	.84943	.54244	.84009	9
52	.49798	.86719	.51304	.85836	.52794	.84928	.54269	.83994	8
53	.49824	.86704	.51329	.85821	.52819	.84913	.54293	.83978	7
54	.49849	.86690	.51354	.85806	.52844	.84897	.54317	.83962	6
55	.49874	.86675	.51379	.85792	.52869	.84882	.54342	.83946	5
56	.49899	.86661	.51404	.85777	.52893	.84866	.54366	.83930	4
57	.49924	.86646	.51429	.85762	.52918	.84851	.54391	.83915	3
58	.49950	.86632	.51454	.85747	.52943	.84836	.54415	.83899	2
59	.49975	.86617	.51479	.85732	.52967	.84820	.54440	.83883	1
60	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	0
′	Cosine 60°	Sine 60°	Cosine 59°	Sine 59°	Cosine 58°	Sine 58°	Cosine 57°	Sine 57°	′

′	33°		34°		35°		36°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosnie	
0	.54464	.83867	.55919	.82904	.57358	.81915	.58779	.80902	60
1	.54488	.83851	.55943	.82887	.57381	.81899	.58802	.80885	59
2	.54513	.83835	.55968	.82871	.57405	.81882	.58826	.80867	58
3	.54537	.83819	.55992	.82855	.57429	.81865	.58849	.80850	57
4	.54561	.83804	.56016	.82839	.57453	.81848	.58873	.80833	56
5	.54586	.83788	.56040	.82822	.57477	.81832	.58896	.80816	55
6	.54610	.83772	.56064	.82806	.57501	.81815	.58920	.80799	54
7	.54635	.83756	.56088	.82790	.57524	.81798	.58943	.80782	53
8	.54659	.83740	.56112	.82773	.57548	.81782	.58967	.80765	52
9	.54683	.83724	.56136	.82757	.57572	.81765	.58990	.80748	51
10	.54708	.83708	.56160	.82741	.57596	.81748	.59014	.80730	50
11	.54732	83692	.56184	.82724	.57619	.81731	.59037	.80713	49
12	.54756	.83676	.56208	.82708	.57643	.81714	.59061	.80696	48
13	.54781	.83660	.56232	.82692	.57667	.81698	.59084	.80679	47
14	.54805	.83645	.56256	.82675	.57691	.81681	.59108	.80662	46
15	.54829	.83629	.56280	.82659	.57715	.81664	.59131	.80644	45
16	.54854	.83613	.56305	.82643	.57738	.81647	.59154	.80627	44
17	.54878	.83597	.56329	.82626	.57762	.81631	.59178	.80610	43
18	.54902	.83581	.56353	.82610	.57786	.81614	.59201	.80593	42
19	.54927	.83565	.56377	.82593	.57810	.81597	.59225	.80576	41
20	.54951	.83549	.56401	.82577	.57833	.81580	.59248	.80558	40
21	.54975	.83533	.56425	.82561	.57857	.81563	.59272	.80541	39
22	.54999	.83517	.56449	.82544	.57881	.81546	.59295	.80524	38
23	.55024	.83501	.56473	.82528	.57904	.81530	.59318	.80507	37
24	.55048	.83485	.56497	.82511	.57928	.81513	.59342	.80489	36
25	.55072	.83469	.56521	.82495	.57952	.81496	.59365	.80472	35
26	.55097	.83453	.56545	.82478	.57976	.81479	.59389	.80455	34
27	.55121	.83437	.56569	.82462	.57999	.81462	.59412	.80438	33
28	.55145	.83421	.56593	.82446	.58023	.81445	.59436	.80420	32
29	.55169	.83405	.56617	.82429	.58047	.81428	.59459	.80403	31
30	.55194	.83389	.56641	.82413	.58070	.81412	.59482	.80386	30
31	.55218	.83373	.56665	.82396	.58094	.81395	.59506	.80368	29
32	.55242	.83356	.56689	.82340	.58118	.81378	.59529	.80351	28
33	.55266	.83340	.56713	.82363	.58141	.81361	.59552	.80334	27
34	.55291	.83324	.56736	.82347	.58165	.81344	.59576	.80316	26
35	.55315	.83308	.56760	.82330	.58189	.81327	.59599	.80299	25
36	.55339	.83292	.56784	.82314	.58212	.81310	.59622	.80282	24
37	.55363	.83276	.56808	.82297	.58236	.81293	.59646	.80264	23
38	.55388	.83260	.56832	.82281	.58260	.81276	.59669	.80247	22
39	.55412	.83244	.56856	.82264	.58283	.81259	.59693	.80230	21
40	.55436	.83228	.56880	.82248	.58307	.81242	.59716	.80212	20
41	.55460	.83212	.56904	.82231	.58330	.81225	.59739	.80195	19
42	.55484	.83195	.56928	.82214	.58354	.81208	.59763	.80178	18
43	.55509	.83179	.56952	.82198	.58378	.81191	.59786	.80160	17
44	.55533	.83163	.56976	.82181	.58401	.81174	.59809	.80143	16
45	.55557	.83147	.57000	.82165	.58425	.81157	.59832	.80125	15
46	.55581	.83131	.57024	.82148	.58449	.81140	.59856	.80108	14
47	.55605	.83115	.57047	.82132	.58472	.81123	.59879	.80091	13
48	.55630	.83098	.57071	.82115	.58496	.81106	.59902	.80073	12
49	.55654	.83082	.57095	.82098	.58519	.81089	.59926	.80056	11
50	.55678	.83066	.57119	.82082	.58543	.81072	.59949	.80038	10
51	.55702	.83050	.57143	.82065	.58567	.81055	.59972	.80021	9
52	.55726	.83034	.57167	.82048	.58590	.81038	.59995	.80003	8
53	.55750	.83017	.57191	.82032	.58614	.81021	.60019	.79986	7
54	.55775	.83001	.57215	.82015	.58637	.81004	.60042	.79968	6
55	.55799	.82985	.57238	.81999	.58661	.80987	.60065	.79951	5
56	.55823	.82969	.57262	.81982	.58684	.80970	.60089	.79934	4
57	.55847	.82953	.57286	.81965	.58708	.80953	.60112	.79916	3
58	.55871	.82936	.57310	.81949	.58731	.80936	.60135	.79899	2
59	.55895	.82920	.57334	.81932	.58755	.80919	.60158	.79881	1
60	.55919	.82904	.57358	.81915	.58779	.80902	.60182	.79864	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	56°		55°		54°		53°		

′	37° Sine	37° Cosine	38° Sine	38° Cosine	39° Sine	39° Cosine	40° Sine	40° Cosine	′
0	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	60
1	.60205	.79846	.61589	.78783	.62955	.77696	.64301	.76586	59
2	.60228	.79829	.61612	.78765	.62977	.77678	.64323	.76567	58
3	.60251	.79811	.61635	.78747	.63000	.77660	.64346	.76548	57
4	.60274	.79793	.61658	.78729	.63022	.77641	.64368	.76530	56
5	.60298	.79776	.61681	.78711	.63045	.77623	.64390	.76511	55
6	.60321	.79758	.61704	.78694	.63068	.77605	.64412	.76492	54
7	.60344	.79741	.61726	.78676	.63090	.77586	.64435	.76473	53
8	.60367	.79723	.61749	.78658	.63113	.77568	.64457	.76455	52
9	.60390	.79706	.61772	.78640	.63135	.77550	.64479	.76436	51
10	.60414	.79688	.61795	.78622	.63158	.77531	.64501	.76417	50
11	.60437	.79671	.61818	.78604	.63180	.77513	.64524	.76398	49
12	.60460	.79653	.61841	.78586	.63203	.77494	.64546	.76380	48
13	.60483	.79635	.61864	.78568	.63225	.77476	.64568	.76361	47
14	.60506	.79618	.61887	.78550	.63248	.77458	.64590	.76342	46
15	.60529	.79600	.61909	.78532	.63271	.77439	.64612	.76323	45
16	.60553	.79583	.61932	.78514	.63293	.77421	.64635	.76304	44
17	.60576	.79565	.61955	.78496	.63316	.77402	.64657	.76286	43
18	.60599	.79547	.61978	.78478	.63338	.77384	.64679	.76267	42
19	.60622	.79530	.62001	.78460	.63361	.77366	.64701	.76248	41
20	.60645	.79512	.62024	.78442	.63383	.77347	.64723	.76229	40
21	.60668	.79494	.62046	.78424	.63406	.77329	.64746	.76210	39
22	.60691	.79477	.62069	.78405	.63428	.77310	.64768	.76192	38
23	.60714	.79459	.62092	.78387	.63451	.77292	.64790	.76173	37
24	.60738	.79441	.62115	.78369	.63473	.77273	.64812	.76154	36
25	.60761	.79424	.62138	.78351	.63496	.77255	.64834	.76135	35
26	.60784	.79406	.62160	.78333	.63518	.77236	.64856	.76116	34
27	.60807	.79388	.62183	.78315	.63540	.77218	.64878	.76097	33
28	.60830	.79371	.62206	.78297	.63563	.77199	.64901	.76078	32
29	.60853	.79353	.62229	.78279	.63585	.77181	.64923	.76059	31
30	.60876	.79335	.62251	.78261	.63608	.77162	.64945	.76041	30
31	.60899	.79318	.62274	.78243	.63630	.77144	.64967	.76022	29
32	.60922	.79300	.62297	.78225	.63653	.77125	.64989	.76003	28
33	.60945	.79282	.62320	.78206	.63675	.77107	.65011	.75984	27
34	.60968	.79264	.62342	.78188	.63698	.77088	.65033	.75965	26
35	.60991	.79247	.62365	.78170	.63720	.77070	.65055	.75946	25
36	.61015	.79229	.62388	.78152	.63742	.77051	.65077	.75927	24
37	.61038	.79211	.62411	.78134	.63765	.77033	.65100	.75908	23
38	.61061	.79193	.62433	.78116	.63787	.77014	.65122	.75889	22
39	.61084	.79176	.62456	.78098	.63810	.76996	.65144	.75870	21
40	.61107	.79158	.62479	.78079	.63832	.76977	.65166	.75851	20
41	.61130	.79140	.62502	.78061	.63854	.76959	.65188	.75832	19
42	.61153	.79122	.62524	.78043	.63877	.76940	.65210	.75813	18
43	.61176	.79105	.62547	.78025	.63899	.76921	.65232	.75794	17
44	.61199	.79087	.62570	.78007	.63922	.76903	.65254	.75775	16
45	.61222	.79069	.62592	.77988	.63944	.76884	.65276	.75756	15
46	.61245	.79051	.62615	.77970	.63966	.76866	.65298	.75738	14
47	.61268	.79033	.62638	.77952	.63989	.76847	.65320	.75719	13
48	.61291	.79016	.62660	.77934	.64011	.76828	.65342	.75700	12
49	.61314	.78998	.62683	.77916	.64033	.76810	.65364	.75680	11
50	.61337	.78980	.62706	.77897	.64056	.76791	.65386	.75661	10
51	.61360	.78962	.62728	.77879	.64078	.76772	.65408	.75642	9
52	.61383	.78944	.62751	.77861	.64100	.76754	.65430	.75623	8
53	.61406	.78926	.62774	.77843	.64123	.76735	.65452	.75604	7
54	.61429	.78908	.62796	.77824	.64145	.76717	.65474	.75585	6
55	.61451	.78891	.62819	.77806	.64167	.76698	.65496	.75566	5
56	.61474	.78873	.62842	.77788	.64190	.76679	.65518	.75547	4
57	.61497	.78855	.62864	.77769	.64212	.76661	.65540	.75528	3
58	.61520	.78837	.62887	.77751	.64234	.76642	.65562	.75509	2
59	.61543	.78819	.62909	.77733	.64256	.76623	.65584	.75490	1
60	.61566	.78801	.62932	.77715	.64279	.76604	.65606	.75471	0
′	52° Cosine	52° Sine	51° Cosine	51° Sine	50° Cosine	50° Sine	49° Cosine	49° Sine	′

′	41° Sine	41° Cosine	42° Sine	42° Cosine	43° Sine	43° Cosine	44° Sine	44° Cosine	′
0	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.65694	.75395	.66999	.74227	.68285	.73056	.69549	.71853	56
5	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	Cosine 48°	Sine 48°	Cosine 47°	Sine 47°	Cosine 46°	Sine 46°	Cosine 45°	Sine 45°	′

′	0° Sec.	0° Co-sec.	1° Sec.	1° Co-sec.	2° Sec.	2° Co-sec.	3° Sec.	3° Co-sec.	′
0	1	Infinite.	1.0001	57.299	1.0006	28.654	1.0014	19.107	60
1	1	3437.70	1.0001	56.359	1.0006	28.417	1.0014	19.002	59
2	1	1718.90	1.0002	55.450	1.0006	28.184	1.0014	18.897	58
3	1	1145.90	1.0002	54.570	1.0006	27.955	1.0014	18.794	57
4	1	859.44	1.0002	53.718	1.0006	27.730	1.0014	18.692	56
5	1	687.55	1.0002	52.891	1.0007	27.508	1.0014	18.591	55
6	1	572.96	1.0002	52.090	1.0007	27.290	1.0015	18.491	54
7	1	491.11	1.0002	51.313	1.0007	27.075	1.0015	18.393	53
8	1	429.72	1.0002	50.558	1.0007	26.864	1.0015	18.295	52
9	1	381.97	1.0002	49.826	1.0007	26.655	1.0015	18.198	51
10	1	343.77	1.0002	49.114	1.0007	26.450	1.0015	18.103	50
11	1	312.52	1.0002	48.422	1.0007	26.249	1.0015	18.008	49
12	1	286.48	1.0002	47.750	1.0007	26.050	1.0016	17.914	48
13	1	264.44	1.0002	47.096	1.0007	25.854	1.0016	17.821	47
14	1	245.55	1.0002	46.460	1.0008	25.661	1.0016	17.730	46
15	1	229.18	1.0002	45.840	1.0008	25.471	1.0016	17.639	45
16	1	214.86	1.0002	45.237	1.0008	25.284	1.0016	17.549	44
17	1	202.22	1.0002	44.650	1.0008	25.100	1.0016	17.460	43
18	1	190.99	1.0002	44.077	1.0008	24.918	1.0017	17.372	42
19	1	180.73	1.0003	43.520	1.0008	24.739	1.0017	17.285	41
20	1	171.89	1.0003	42.976	1.0008	24.562	1.0017	17.198	40
21	1	163.70	1.0003	42.445	1.0008	24.358	1.0017	17.113	39
22	1	156.26	1.0003	41.928	1.0008	24.216	1.0017	17.028	38
23	1	149.47	1.0003	41.423	1.0009	24.047	1.0017	16.944	37
24	1	143.24	1.0003	40.930	1.0009	23.880	1.0018	16.861	36
25	1	137.51	1.0003	40.448	1.0009	23.716	1.0018	16.779	35
26	1	132.22	1.0003	39.978	1.0009	23.553	1.0018	16.698	34
27	1	127.32	1.0003	39.518	1.0009	23.393	1.0018	16.617	33
28	1	122.78	1.0003	39.069	1.0009	23.235	1.0018	16.538	32
29	1	118.54	1.0003	38.631	1.0009	23.079	1.0018	16.459	31
30	1	114.59	1.0003	38.201	1.0009	22.925	1.0019	16.380	30
31	1	110.90	1.0003	37.782	1.0010	22.774	1.0019	16.303	29
32	1	107.43	1.0003	37.371	1.0010	22.624	1.0019	16.226	28
33	1	104.17	1.0004	36.969	1.0010	22.476	1.0019	16.150	27
34	1	101.11	1.0004	36.576	1.0010	22.330	1.0019	16.075	26
35	1	98.223	1.0004	36.191	1.0010	22.186	1.0019	16.000	25
36	1	95.495	1.0004	35.814	1.0010	22.044	1.0020	15.926	24
37	1	92.914	1.0004	35.445	1.0010	21.904	1.0020	15.853	23
38	1.0001	92.469	1.0004	35.084	1.0010	21.765	1.0020	15.780	22
39	1.0001	88.149	1.0004	34.729	1.0011	21.629	1.0020	15.708	21
40	1.0001	85.946	1.0004	34.382	1.0011	21.494	1.0020	15.637	20
41	1.0001	83.849	1.0004	34.042	1.0011	21.360	1.0021	15.566	19
42	1.0001	81.853	1.0004	33.708	1.0011	21.228	1.0021	15.496	18
43	1.0001	79.950	1.0004	33.381	1.0011	21.098	1.0021	15.427	17
44	1.0001	78.133	1.0004	33.060	1.0011	20.970	1.0021	15.358	16
45	1.0001	76.396	1.0005	32.745	1.0011	20.843	1.0021	15.290	15
46	1.0001	74.736	1.0005	32.437	1.0012	20.717	1.0022	15.222	14
47	1.0001	73.146	1.0005	32.134	1.0012	20.593	1.0022	15.155	13
48	1.0001	71.622	1.0005	31.836	1.0012	20.471	1.0022	15.089	12
49	1.0001	71.160	1.0005	31.544	1.0012	20.350	1.0022	15.023	11
50	1.0001	68.757	1.0005	31.257	1.0012	20.230	1.0022	14.958	10
51	1.0001	67.409	1.0005	30.976	1.0012	20.112	1.0023	14.893	9
52	1.0001	66.113	1.0005	30.699	1.0012	19.995	1.0023	14.829	8
53	1.0001	64.866	1.0005	30.428	1.0013	19.880	1.0023	14.765	7
54	1.0001	63.664	1.0005	30.161	1.0013	19.766	1.0023	14.702	6
55	1.0001	62.507	1.0005	29.899	1.0013	19.653	1.0023	14.640	5
56	1.0001	61.391	1.0006	29.641	1.0013	19.541	1.0024	14.578	4
57	1.0001	61.314	1.0006	29.388	1.0013	19.431	1.0024	14.517	3
58	1.0001	59.274	1.0006	29.139	1.0013	19.322	1.0024	14.456	2
59	1.0001	58.270	1.0006	28.894	1.0013	19.214	1.0024	14.395	1
60	1.0001	57.299	1.0006	28.654	1.0014	19.107	1.0024	14.335	0
′	89° Co-sec.	89° Sec.	88° Co-sec.	88° Sec.	87° Co-sec.	87° Sec.	86° Co-sec.	86° Sec.	′

′	4°		5°		6°		7°		′
	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	
0	1.0024	14.335	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	60
1	1.0025	14.276	1.0038	11.436	1.0055	9.5404	1.0075	8.1861	59
2	1.0025	14.217	1.0039	11.398	1.0056	9.5141	1.0076	8.1668	58
3	1.0025	14.159	1.0039	11.360	1.0056	9.4880	1.0076	8.1476	57
4	1.0025	14.101	1.0039	11.323	1.0056	9.4620	1.0076	8.1285	56
5	1.0025	14.043	1.0039	11.286	1.0057	9.4362	1.0077	8.1094	55
6	1.0026	13.986	1.0040	11.249	1.0057	9.4105	1.0077	8.0905	54
7	1.0026	13.930	1.0040	11.213	1.0057	9.3850	1.0078	8.0717	53
8	1.0026	13.874	1.0040	11.176	1.0057	9.3596	1.0078	8.0529	52
9	1.0026	13.818	1.0040	11.140	1.0058	9.3343	1.0078	8.0342	51
10	1.0026	13.763	1.0041	11.104	1.0058	9.3092	1.0079	8.0156	50
11	1.0027	13.708	1.0041	11.069	1.0058	9.2842	1.0079	7.9971	49
12	1.0027	13.654	1.0041	11.033	1.0059	9.2593	1.0079	7.9787	48
13	1.0027	13.600	1.0041	10.988	1.0059	9.2346	1.0080	7.9604	47
14	1.0027	13.547	1.0042	10.963	1.0059	9.2100	1.0080	7.9421	46
15	1.0027	13.494	1.0042	10.929	1.0060	9.1855	1.0080	7.9240	45
16	1.0028	13.441	1.0042	10.894	1.0060	9.1612	1.0081	7.9059	44
17	1.0028	13.389	1.0043	10.860	1.0060	9.1370	1.0081	7.8879	43
18	1.0028	13.337	1.0043	10.826	1.0061	9.1129	1.0082	7.8700	42
19	1.0028	13.286	1.0043	10.792	1.0061	9.0890	1.0082	7.8522	41
20	1.0029	13.235	1.0043	10.758	1.0061	9.0651	1.0082	7.8344	40
21	1.0029	13.184	1.0044	10.725	1.0062	9.0414	1.0083	7.8168	39
22	1.0029	13.134	1.0044	10.692	1 0062	9.0179	1.0083	7.7992	38
23	1.0029	13.084	1.0044	10.659	1.0062	8.9944	1.0084	7.7817	37
24	1.0029	13.034	1.0044	10.626	1.0063	8.9711	1.0084	7.7642	36
25	1.0030	12.985	1.0045	10.593	1.0063	8.9479	1.0084	7.7469	35
26	1.0030	12.937	1.0045	10.561	1.0063	8.9248	1.0085	7.7296	34
27	1.0030	12.888	1.0045	10.529	1.0064	8.9018	1.0085	7.7124	33
28	1.0030	12.840	1.0046	10.497	1.0064	8.8790	1.0085	7.6953	32
29	1.0031	12.793	1.0046	10.465	1.0064	8.8563	1.0086	7.6783	31
30	1.0031	12.745	1.0046	10.433	1.0065	8.8337	1.0086	7.6613	30
31	1.0031	12.698	1.0046	10.402	1.0065	8.8112	1.0087	7.6444	29
32	1.0031	12.652	1.0047	10.371	1.0065	8.7888	1.0087	7.6276	28
33	1.0032	12.606	1.0047	10.340	1.0066	8.7665	1.0087	7.6108	27
34	1.0032	12.560	1.0047	10.309	1.0066	8.7444	1.0088	7.5942	26
35	1.0032	12.514	1.0048	10.278	1.0066	8.7223	1.0088	7.5776	25
36	1.0032	12.469	1.0048	10.248	1.0067	8.7004	1.0089	7.5611	24
37	1.0032	12.424	1.0048	10.217	1.0067	8.6786	1.0089	7.5446	23
38	1.0033	12.379	1.0048	10.187	1.0067	8.6569	1.0089	7.5282	22
39	1.0033	12.335	1.0049	10.157	1.0068	8.6353	1.0090	7.5119	21
40	1.0033	12.291	1.0049	10.127	1.0068	8.6138	1.0090	7.4957	20
41	1.0033	12.248	1.0049	10.098	1.0068	8.5924	1.0090	7.4795	19
42	1.0034	12.204	1.0050	10.068	1.0069	8.5711	1.0091	7.4634	18
43	1.0034	12.161	1.0050	10.039	1.0069	8.5499	1.0091	7.4474	17
44	1.0034	12.118	1.0050	10.010	1.0069	8.5289	1.0092	7.4315	16
45	1.0034	12.076	1.0050	9.9812	1.0070	8.5079	1.0092	7.4156	15
46	1.0035	12.034	1.0051	9.9525	1.0070	8.4871	1.0092	7.3998	14
47	1.0035	11.992	1.0051	9.9239	1.0070	8.4663	1.0093	7.3840	13
48	1.0035	11.950	1.0051	9.8955	1.0071	8.4457	1.0093	7.3683	12
49	1.0035	11.909	1.0052	9.8672	1.0071	8.4251	1.0094	7.3527	11
50	1.0036	11.868	1.0052	9.8391	1.0071	8.4046	1.0094	7.3372	10
51	1.0036	11.828	1.0052	9.8112	1.0072	8.3843	1.0094	7.3217	9
52	1.0036	11.787	1.0053	9.7834	1.0072	8.3640	1.0095	7.3063	8
53	1.0036	11.747	1.0053	9.7558	1.0073	8.3439	1.0095	7.2909	7
54	1.0037	11.707	1.0053	9.7283	1.0073	8.3238	1.0096	7.2757	6
55	1.0037	11.668	1.0053	9.7010	1.0073	8.3039	1.0096	7.2604	5
56	1.0037	11.628	1.0054	9.6739	1.0074	8.2840	1.0097	7.2453	4
57	1.0037	11.589	1.0054	9.6469	1.0074	8.2642	1.0097	7.2302	3
58	1.0038	11.550	1.0054	9.6200	1.0074	8.2446	1.0097	7.2152	2
59	1.0038	11.512	1.0055	9.5933	1.0075	8.2250	1.0098	7.2002	1
60	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	1.0098	7.1853	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	85°		84°		83°		82°		

′	8° Sec.	8° Co-sec.	9° Sec.	9° Co-sec.	10° Sec.	10° Co-sec.	11° Sec.	11° Co-sec.	′
0	1.0098	7.1853	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	60
1	1.0099	7.1704	1.0125	6.3807	1.0155	5.7493	1.0188	5.2330	59
2	1.0099	7.1557	1.0125	6.3690	1.0155	5.7398	1.0188	5.2252	58
3	1.0099	7.1409	1.0126	6.3574	1.0156	5.7304	1.0189	5.2174	57
4	1.0100	7.1263	1.0126	6.3458	1.0156	5.7210	1.0189	5.2097	56
5	1.0100	7.1117	1.0127	6.3343	1.0157	5.7117	1.0190	5.2019	55
6	1.0101	7.0972	1.0127	6.3228	1.0157	5.7023	1.0191	5.1942	54
7	1.0101	7.0827	1.0128	6.3113	1.0158	5.6930	1.0191	5.1865	53
8	1.0102	7.0683	1.0128	6.2999	1.0158	5.6838	1.0192	5.1788	52
9	1.0102	7.0539	1.0129	6.2885	1.0159	5.6745	1.0192	5.1712	51
10	1.0102	7.0396	1.0129	6.2772	1.0159	5.6653	1.0193	5.1636	50
11	1.0103	7.0254	1.0130	6.2659	1.0160	5.6561	1.0193	5.1560	49
12	1.0103	7.0112	1.0130	6.2546	1.0160	5.6470	1.0194	5.1484	48
13	1.0104	6.9971	1.0131	6.2434	1.0161	5.6379	1.0195	5.1409	47
14	1.0104	6.9830	1.0131	6.2322	1.0162	5.6288	1.0195	5.1333	46
15	1.0104	6.9690	1.0132	6.2211	1.0162	5.6197	1.0196	5.1258	45
16	1.0105	6.9550	1.0132	6.2100	1.0163	5.6107	1.0196	5.1183	44
17	1.0105	6.9411	1.0133	6.1990	1.0163	5.6017	1.0197	5.1109	43
18	1.0106	6.9273	1.0133	6.1880	1.0164	5.5928	1.0198	5.1034	42
19	1.0106	6.9135	1.0134	6.1770	1.0164	5.5838	1.0198	5.0960	41
20	1.0107	6.8998	1.0134	6.1661	1.0165	5.5749	1.0199	5.0886	40
21	1.0107	6.8861	1.0135	6.1552	1.0165	5.5660	1.0199	5.0812	39
22	1.0107	6.8725	1.0135	6.1443	1.0166	5.5572	1.0200	5.0739	38
23	1.0108	6.8589	1.0136	6.1335	1.0166	5.5484	1.0201	5.0666	37
24	1.0108	6.8454	1.0136	6.1227	1.0167	5.5396	1.0201	5.0593	36
25	1.0109	6.8320	1.0136	6.1120	1.0167	5.5308	1.0202	5.0520	35
26	1.0109	6.8185	1.0137	6.1013	1.0168	5.5221	1.0202	5.0447	34
27	1.0110	6.8052	1.0137	6.0906	1.0169	5.5134	1.0203	5.0375	33
28	1.0110	6.7919	1.0138	6.0800	1.0169	5.5047	1.0204	5.0302	32
29	1.0111	6.7787	1.0138	6.0694	1.0170	5.4960	1.0204	5.0230	31
30	1.0111	6.7655	1.0139	6.0588	1.0170	5.4874	1.0205	5.0158	30
31	1.0111	6.7523	1.0139	6.0483	1.0171	5.4788	1.0205	5.0087	29
32	1.0112	6.7392	1.0140	6.0379	1.0171	5.4702	1.0206	5.0015	28
33	1.0112	6.7262	1.0140	6.0274	1.0172	5.4617	1.0207	4.9944	27
34	1.0113	6.7132	1.0141	6.0170	1.0172	5.4532	1.0207	4.9873	26
35	1.0113	6.7003	1.0141	6.0066	1.0173	5.4447	1.0208	4.9802	25
36	1.0114	6.6874	1.0142	5.9963	1.0174	5.4362	1.0208	4.9732	24
37	1.0114	6.6745	1.0142	5.9860	1.0174	5.4278	1.0209	4.9661	23
38	1.0115	6.6617	1.0143	5.9758	1.0175	5.4194	1.0210	4.9591	22
39	1.0115	6.6490	1.0143	5.9655	1.0175	5.4110	1.0210	4.9521	21
40	1.0115	6.6363	1.0144	5.9554	1.0176	5.4026	1.0211	4.9452	20
41	1.0116	6.6237	1.0144	5.9452	1.0176	5.3943	1.0211	4.9382	19
42	1.0116	6.6111	1.0145	5.9351	1.0177	5.3860	1.0212	4.9313	18
43	1.0117	6.5985	1.0145	5.9250	1.0177	5.3777	1.0213	4.9243	17
44	1.0117	6.5860	1.0146	5.9150	1.0178	5.3695	1.0213	4.9175	16
45	1.0118	6.5736	1.0146	5.9049	1.0179	5.3612	1.0214	4.9106	15
46	1.0118	6.5612	1.0147	5.8950	1.0179	5.3530	1.0215	4.9037	14
47	1.0119	6.5488	1.0147	5.8850	1.0180	5.3449	1.0215	4.8969	13
48	1.0119	6.5365	1.0148	5.8751	1.0180	5.3367	1.0216	4.8901	12
49	1.0119	6.5243	1.0148	5.8652	1.0181	5.3286	1.0216	4.8833	11
50	1.0120	6.5121	1.0149	5.8554	1.0181	5.3205	1.0217	4.8765	10
51	1.0120	6.4999	1.0150	5.8456	1.0182	5.3124	1.0218	4.8697	9
52	1.0121	6.4878	1.0150	5.8358	1.0182	5.3044	1.0218	4.8630	8
53	1.0121	6.4757	1.0151	5.8261	1.0183	5.2963	1.0219	4.8563	7
54	1.0122	6.4637	1.0151	5.8163	1.0184	5.2883	1.0220	4.8496	6
55	1.0122	6.4517	1.0152	5.8067	1.0184	5.2803	1.0220	4.8429	5
56	1.0123	6.4398	1.0152	5.7970	1.0185	5.2724	1.0221	4.8362	4
57	1.0123	6.4279	1.0153	5.7874	1.0185	5.2645	1.0221	4.8296	3
58	1.0124	6.4160	1.0153	5.7778	1.0186	5.2566	1.0222	4.8229	2
59	1.0124	6.4042	1.0154	5.7683	1.0186	5.2487	1.0223	4.8163	1
60	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	1.0223	4.8097	0
′	81° Co-sec.	81° Sec.	80° Co-sec.	80° Sec.	79° Co-sec.	79° Sec.	78° Co-sec.	78° Sec.	′

′	12° Sec.	12° Co-sec.	13° Sec.	13° Co-sec.	14° Sec.	14° Co-sec.	15° Sec.	15° Co-sec.	′
0	1.0223	4.8097	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	60
1	1.0224	4.8032	1.0264	4.4398	1.0307	4.1287	1.0353	3.8595	59
2	1.0225	4.7966	1.0264	4.4342	1.0308	4.1239	1.0354	3.8553	58
3	1.0225	4.7901	1.0265	4.4287	1.0308	4.1191	1.0355	3.8512	57
4	1.0226	4.7835	1.0266	4.4231	1.0309	4.1144	1.0356	3.8470	56
5	1.0226	4.7770	1.0266	4.4176	1.0310	4.1096	1.0357	3.8428	55
6	1.0227	4.7706	1.0267	4.4121	1.0311	4.1048	1.0358	3.8387	54
7	1.0228	4.7641	1.0268	4.4065	1.0311	4.1001	1.0358	3.8346	53
8	1.0228	4.7576	1.0268	4.4011	1.0312	4.0953	1.0359	3.8304	52
9	1.0229	4.7512	1.0269	4.3956	1.0313	4.0906	1.0360	3.8263	51
10	1.0230	4.7448	1.0270	4.3910	1.0314	4.0859	1.0361	3.8222	50
11	1.0230	4.7384	1.0271	4.3847	1.0314	4.0812	1.0362	3.8181	49
12	1.0231	4.7320	1.0271	4.3792	1.0315	4.0765	1.0362	3.8140	48
13	1.0232	4.7257	1.0272	4.3738	1.0316	4.0718	1.0363	3.8100	47
14	1.0232	4.7193	1.0273	4.3684	1.0317	4.0672	1.0364	3.8059	46
15	1.0233	4.7130	1.0273	4.3630	1.0317	4.0625	1.0365	3.8018	45
16	1.0234	4.7067	1.0274	4.3576	1.0318	4.0579	1.0366	3.7978	44
17	1.0234	4.7004	1.0275	4.3522	1.0319	4.0532	1.0367	3.7937	43
18	1.0235	4.6942	1.0276	4.3469	1.0320	4.0486	1.0367	3.7897	42
19	1.0235	4.6879	1.0276	4.3415	1.0320	4.0440	1.0368	3.7857	41
20	1.0236	4.6817	1.0277	4.3362	1.0321	4.0394	1.0369	3.7816	40
21	1.0237	4.6754	1.0278	4.3309	1.0322	4.0348	1.0370	3.7776	39
22	1.0237	4.6692	1.0278	4.3256	1.0323	4.0302	1.0371	3.7736	38
23	1.0238	4.6631	1.0279	4.3203	1.0323	4.0256	1.0371	3.7697	37
24	1.0239	4.6569	1.0280	4.3150	1.0324	4.0211	1.0372	3.7657	36
25	1.0239	4.6507	1.0280	4.3098	1.0325	4.0165	1.0373	3.7617	35
26	1.0240	4.6446	1.0281	4.3045	1.0326	4.0120	1.0374	3.7577	34
27	1.0241	4.6385	1.0282	4.2993	1.0327	4.0074	1.0375	3.7538	33
28	1.0241	4.6324	1.0283	4.2941	1.0327	4.0029	1.0376	3.7498	32
29	1.0242	4.6263	1.0283	4.2888	1.0328	3.9984	1.0376	3.7459	31
30	1.0243	4.6202	1.0284	4.2836	1.0329	3.9939	1.0377	3.7420	30
31	1.0243	4.6142	1.0285	4.2785	1.0330	3.9894	1.0378	3.7380	29
32	1.0244	4.6081	1.0285	4.2733	1.0330	3.9850	1.0379	3.7341	28
33	1.0245	4.6021	1.0286	4.2681	1.0331	3.9805	1.0380	3.7302	27
34	1.0245	4.5961	1.0287	4.2630	1.0332	3.9760	1.0381	3.7263	26
35	1.0246	4.5901	1.0288	4.2579	1.0333	3.9716	1.0382	3.7224	25
36	1.0247	4.5841	1.0288	4.2527	1.0334	3.9672	1.0382	3.7186	24
37	1.0247	4.5782	1.0289	4.2476	1.0334	3.9627	1.0383	3.7147	23
38	1.0248	4.5722	1.0290	4.2425	1.0335	3.9583	1.0384	3.7108	22
39	1.0249	4.5663	1.0291	4.2375	1.0336	3.9539	1.0385	3.7070	21
40	1.0249	4.5604	1.0291	4.2324	1.0337	3.9495	1.0386	3.7031	20
41	1.0250	4.5545	1.0292	4.2273	1.0338	3.9451	1.0387	3.6993	19
42	1.0251	4.5486	1.0293	4.2223	1.0338	3.9408	1.0387	3.6955	18
43	1.0251	4.5428	1.0293	4.2173	1.0339	3.9364	1.0388	3.6917	17
44	1.0252	4.5369	1.0294	4.2122	1.0340	3.9320	1.0389	3.6878	16
45	1.0253	4.5311	1.0295	4.2072	1.0341	3.9277	1.0390	3.6840	15
46	1.0253	4.5253	1.0296	4.2022	1.0341	3.9234	1.0391	3.6802	14
47	1.0254	4.5195	1.0296	4.1972	1.0342	3.9199	1.0392	3.6765	13
48	1.0255	4.5137	1.0297	4.1923	1.0343	3.9147	1.0393	3.6727	12
49	1.0255	4.5079	1.0298	4.1873	1.0344	3.9104	1.0393	3.6689	11
50	1.0256	4.5021	1.0299	4.1824	1.0345	3.9061	1.0394	3.6651	10
51	1.0257	4.4964	1.0299	4.1774	1.0345	3.9018	1.0395	3.6614	9
52	1.0257	4.4907	1.0300	4.1725	1.0346	3.8976	1.0396	3.6576	8
53	1.0258	4.4850	1.0301	4.1676	1.0347	3.8933	1.0397	3.6539	7
54	1.0259	4.4793	1.0302	4.1627	1.0348	3.8990	1.0398	3.6502	6
55	1.0260	4.4736	1.0302	4.1578	1.0349	3.8848	1.0399	3.6464	5
56	1.0260	4.4679	1.0303	4.1529	1.0349	3.8805	1.0399	3.6427	4
57	1.0261	4.4623	1.0304	4.1481	1.0350	3.8763	1.0400	3.6390	3
58	1.0262	4.4566	1.0305	4.1432	1.0351	3.8721	1.0401	3.6353	2
59	1.0262	4.4510	1.0305	4.1384	1.0352	3.8679	1.0402	3.6316	1
60	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	1.0403	3.6279	0
′	Co-sec. 77°	Sec. 77°	Co-sec. 76°	Sec. 76°	Co-sec. 75°	Sec. 75°	Co-sec. 74°	Sec. 74°	′

′	16° Sec.	16° Co-sec.	17° Sec.	17° Co-sec.	18° Sec.	18° Co-sec.	19° Sec.	19° Co-sec.	′
0	1.0403	3.6279	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	60
1	1.0404	3.6243	1.0458	3.4170	1.0516	3.2332	1.0577	3.0690	59
2	1.0405	3.6206	1.0459	3.4138	1.0517	3.2303	1.0578	3.0664	58
3	1.0406	3.6169	1.0460	3.4106	1.0518	3.2274	1.0579	3.0638	57
4	1.0406	3.6133	1.0461	3.4073	1.0519	3.2245	1.0580	3.0612	56
5	1.0407	5.6096	1.0461	3.4041	1.0520	3.2216	1.0581	3.0586	55
6	1.0408	3.6060	1.0462	3.4009	1.0521	3.2188	1.0582	3.0561	54
7	1.0409	3.6024	1.0463	3.3977	1.0522	3.2159	1.0584	3.0535	53
8	1.0410	3.5987	1.0464	3.3945	1.0523	3.2131	1.0585	3.0509	52
9	1.0411	3.5951	1.0465	3.3913	1.0524	3.2102	1.0586	3.0484	51
10	1.0412	3.5915	1.0466	3.3881	1.0525	3.2074	1.0587	3.0458	50
11	1.0413	3.5879	1.0467	3.3849	1.0526	3.2045	1.0588	3.0433	49
12	1.0413	3.5843	1.0468	3.3817	1.0527	3.2017	1.0589	3.0407	48
13	1.0414	3.5807	1.0469	3.3785	1.0528	3.1989	1.0590	3.0382	47
14	1.0415	3.5772	1.0470	3.3754	1.0529	3.1960	1.0591	3.0357	46
15	1.0416	3.5736	1.0471	3.3722	1.0530	3.1932	1.0592	3.0331	45
16	1.0417	3.5700	1.0472	3.3690	1.0531	3.1904	1.0593	3.0306	44
17	1.0418	3.5665	1.0473	3.3659	1.0532	3.1876	1.0594	3.0281	43
18	1.0419	3.5629	1.0474	3.3627	1.0533	3.1848	1.0595	3.0256	42
19	1.0420	3.5594	1.0475	3.3596	1.0534	3.1820	1.0596	3.0231	41
20	1.0420	3.5559	1.0476	3.3565	1.0535	3.1792	1.0598	3.0206	40
21	1.0421	3.5523	1.0477	3.3534	1.0536	3.1764	1.0599	3.0181	39
22	1.0422	3.5488	1.0478	3.3502	1.0537	3.1736	1.0600	3.0156	38
23	1.0423	3.5453	1.0478	3.3471	1.0538	3.1708	1.0601	3.0131	37
24	1.0424	3.5418	1.0479	3.3440	1.0539	3.1681	1.0602	3.0106	36
25	1.0425	3.5383	1.0480	3.3409	1.0540	3.1653	1.0603	3.0081	35
26	1.0426	3.5348	1.0481	3.3378	1.0541	3.1625	1.0604	3.0056	34
27	1.0427	3.5313	1.0482	3.3347	1.0542	3.1598	1.0605	3.0031	33
28	1.0428	3.5279	1.0483	3.3316	1.0543	3.1570	1.0606	3.0007	32
29	1.0428	3.5244	1.0484	3.3286	1.0544	3.1543	1.0607	2.9982	31
30	1.0429	3.5209	1.0485	3.3255	1.0545	3.1515	1.0608	2.9957	30
31	1.0430	3.5175	1.0486	3.3224	1.0546	3.1488	1.0609	2.9933	29
32	1.0431	3.5140	1.0487	3.3194	1.0547	3.1461	1.0611	2.9908	28
33	1.0432	3.5106	1.0488	3.3163	1.0548	3.1433	1.0612	2.9884	27
34	1.0433	3.5072	1.0489	3.3133	1.0549	3.1406	1.0613	2.9859	26
35	1.0434	3.5037	1.0490	3.3102	1.0550	3.1379	1.0614	2.9835	25
36	1.0435	3.5003	1.0491	3.3072	1.0551	3.1352	1.0615	2.9810	24
37	1.0436	3.4969	1.0492	3.3042	1.0552	3.1325	1.0616	2.9786	23
38	1.0437	3.4935	1.0493	3.3011	1.0553	3.1298	1.0617	2.9762	22
39	1.0438	3.4901	1.0494	3.2981	1.0554	3.1271	1.0618	2.9738	21
40	1.0438	3.4867	1.0495	3.2951	1.0555	3.1244	1.0619	2.9713	20
41	1.0439	3.4833	1.0496	3.2921	1.0556	3.1217	1.0620	2.9689	19
42	1.0440	3.4799	1.0497	3.2891	1.0557	3.1190	1.0622	2.9665	18
43	1.0441	3.4766	1.0498	3.2861	1.0558	3.1163	1.0623	2.9641	17
44	1.0442	3.4732	1.0499	3.2831	1.0559	3.1137	1.0624	2.9617	16
45	1.0443	3.4698	1.0500	3.2801	1.0560	3.1110	1.0625	2.9593	15
46	1.0444	3.4665	1.0501	3.2772	1.0561	3.1083	1.0626	2.9569	14
47	1.0445	3.4632	1.0502	3.2742	1.0562	3.1057	1.0627	2.9545	13
48	1.0446	3.4598	1.0503	3.2712	1.0563	3.1030	1.0628	2.9521	12
49	1.0447	3.4565	1.0504	3.2683	1.0565	3.1004	1.0629	2.9497	11
50	1.0448	3.4532	1.0505	3.2653	1.0566	3.0977	1.0630	2.9474	10
51	1.0448	3.4498	1.0506	3.2624	1.0567	3.0951	1.0632	2.9450	9
52	1.0449	3.4465	1.0507	3.2594	1.0568	3.0925	1.0633	2.9426	8
53	1.0450	3.4432	1.0508	3.2565	1.0569	3.0898	1.0634	2.9402	7
54	1.0451	3.4399	1.0509	3.2535	1.0570	3.0872	1.0635	2.9379	6
55	1.0452	3.4366	1.0510	3.2506	1.0571	3.0846	1.0636	2.9355	5
56	1.0453	3.4334	1.0511	3.2477	1.0572	3.0820	1.0637	2.9332	4
57	1.0454	3.4301	1.0512	3.2448	1.0573	3.0793	1.0638	2.9308	3
58	1.0455	3.4268	1.0513	3.2419	1.0574	3.0767	1.0639	2.9285	2
59	1.0456	3.4236	1.0514	3.2390	1.0575	3.0741	1.0641	2.9261	1
60	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	1.0642	2.9238	0
′	Co-sec. 73°	Sec. 73°	Co-sec. 72°	Sec. 72°	Co-sec. 71°	Sec. 71°	Co-sec. 70°	Sec. 70°	′

′	20° Sec.	20° Co-sec.	21° Sec.	21° Co-sec.	22° Sec.	22° Co-sec.	23° Sec.	23° Co-sec.	′
0	1.0642	2.9238	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	60
1	1.0643	2.9215	1.0713	2.7883	1.0787	2.6675	1.0865	2.5575	59
2	1.0644	2.9191	1.0714	2.7862	1.0788	2.6656	1.0866	2.5558	58
3	1.0645	2.9168	1.0715	2.7841	1.0789	2.6637	1.0868	2.5540	57
4	1.0646	2.9145	1.0716	2.7820	1.0790	2.6618	1.0869	2.5523	56
5	1.0647	2.9122	1.0717	2.7799	1.0792	2.6599	1.0870	2.5506	55
6	1.0648	2.9098	1.0719	2.7778	1.0793	2.6580	1.0872	2.5488	54
7	1.0650	2.9075	1.0720	2.7757	1.0794	2.6561	1.0873	2.5471	53
8	1.0651	2.9052	1.0721	2.7736	1.0795	2.6542	1.0874	2.5453	52
9	1.0652	2.9029	1.0722	2.7715	1.0797	2.6523	1.0876	2.5436	51
10	1.0653	2.9006	1.0723	2.7694	1.0798	2.6504	1.0877	2.5419	50
11	1.0654	2.8983	1.0725	2.7674	1.0799	2.6485	1.0878	2.5402	49
12	1.0655	2.8960	1.0726	2.7653	1.0801	2.6466	1.0880	2.5384	48
13	1.0656	2.8937	1.0727	2.7632	1.0802	2.6447	1.0881	2.5367	47
14	1.0658	2.8915	1.0728	2.7611	1.0803	2.6428	1.0882	2.5350	46
15	1.0659	2.8892	1.0729	2.7591	1.0804	2.6410	1.0884	2.5333	45
16	1.0660	2.8869	1.0731	2.7570	1.0806	2.6391	1.0885	2.5316	44
17	1.0661	2.8846	1.0732	2.7550	1.0807	2.6372	1.0886	2.5299	43
18	1.0662	2.8824	1.0733	2.7529	1.0808	2.6353	1.0888	2.5281	42
19	1.0663	2.8801	1.0734	2.7509	1.0810	2.6335	1.0889	2.5264	41
20	1.0664	2.8778	1.0736	2.7488	1.0811	2.6316	1.0891	2.5247	40
21	1.0666	2.8756	1.0737	2.7468	1.0812	2.6297	1.0892	2.5230	39
22	1.0667	2.8733	1.0738	2.7447	1.0813	2.6279	1.0893	2.5213	38
23	1.0668	2.8711	1.0739	2.7427	1.0815	2.6260	1.0895	2.5196	37
24	1.0669	2.8688	1.0740	2.7406	1.0816	2.6242	1.0896	2.5179	36
25	1.0670	2.8666	1.0742	2.7386	1.0817	2.6223	1.0897	2.5163	35
26	1.0671	2.8644	1.0743	2.7366	1.0819	2.6205	1.0899	2.5146	34
27	1.0673	2.8621	1.0744	2.7346	1.0820	2.6186	1.0900	2.5129	33
28	1.0674	2.8599	1.0745	2.7325	1.0821	2.6168	1.0902	2.5112	32
29	1.0675	2.8577	1.0747	2.7305	1.0823	2.6150	1.0903	2.5095	31
30	1.0676	2.8554	1.0748	2.7285	1.0824	2.6131	1.0904	2.5078	30
31	1.0677	2.8532	1.0749	2.7265	1.0825	2.6113	1.0906	2.5062	29
32	1.0678	2.8510	1.0750	2.7245	1.0826	2.6095	1.0907	2.5045	28
33	1.0679	2.8488	1.0751	2.7225	1.0828	2.6076	1.0908	2.5028	27
34	1.0681	2.8466	1.0753	2.7205	1.0829	2.6058	1.0910	2.5011	26
35	1.0682	2.8444	1.0754	2.7185	1.0830	2.6040	1.0911	2.4995	25
36	1.0683	2.8422	1.0755	2.7165	1.0832	2.6022	1.0913	2.4978	24
37	1.0684	2.8400	1.0756	2.7145	1.0833	2.6003	1.0914	2.4961	23
38	1.0685	2.8378	1.0758	2.7125	1.0834	2.5985	1.0915	2.4945	22
39	1.0686	2.8356	1.0759	2.7105	1.0836	2.5967	1.0917	2.4928	21
40	1.0688	2.8334	1.0760	2.7085	1.0837	2.5949	1.0918	2.4912	20
41	1.0689	2.8312	1.0761	2.7065	1.0838	2.5931	1.0920	2.4895	19
42	1.0690	2.8290	1.0763	2.7045	1.0840	2.5913	1.0921	2.4879	18
43	1.0691	2.8269	1.0764	2.7026	1.0841	2.5895	1.0922	2.4862	17
44	1.0692	2.8247	1.0765	2.7006	1.0842	2.5877	1.0924	2.4846	16
45	1.0694	2.8225	1.0766	2.6986	1.0844	2.5859	1.0925	2.4829	15
46	1.0695	2.8204	1.0768	2.6967	1.0845	2.5841	1.0927	2.4813	14
47	1.0696	2.8182	1.0769	2.6947	1.0846	2.5823	1.0928	2.4797	13
48	1.0697	2.8160	1.0770	2.6927	1.0847	2.5805	1.0929	2.4780	12
49	1.0698	2.8139	1.0771	2.6908	1.0849	2.5787	1.0931	2.4764	11
50	1.0699	2.8117	1.0773	2.6888	1.0850	2.5770	1.0932	2.4748	10
51	1.0701	2.8096	1.0774	2.6869	1.0851	2.5752	1.0934	2.4731	9
52	1.0702	2.8074	1.0775	2.6849	1.0853	2.5734	1.0935	2.4715	8
53	1.0703	2.8053	1.0776	2.6830	1.0854	2.5716	1.0936	2.4699	7
54	1.0704	2.8032	1.0778	2.6810	1.0855	2.5699	1.0938	2.4683	6
55	1.0705	2.8010	1.0779	2.6791	1.0857	2.5681	1.0939	2.4666	5
56	1.0707	2.7989	1.0780	2.6772	1.0858	2.5663	1.0941	2.4650	4
57	1.0708	2.7968	1.0781	2.6752	1.0859	2.5646	1.0942	2.4634	3
58	1.0709	2.7947	1.0783	2.6733	1.0861	2.5628	1.0943	2.4618	2
59	1.0710	2.7925	1.0784	2.6714	1.0862	2.5610	1.0945	2.4602	1
60	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	1.0946	2.4586	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	69°		68°		67°		66°		

′	24° Sec.	24° Co-sec.	25° Sec.	25° Co-sec.	26° Sec.	26° Co-sec.	27° Sec.	27° Co-sec.	′
0	1.0946	2.4586	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	60
1	1.0948	2.4570	1.1035	2.3647	1.1127	2.2798	1.1225	2.2014	59
2	1.0949	2.4554	1.1037	2.3632	1.1129	2.2784	1.1226	2.2002	58
3	1.0951	2.4538	1.1038	2.3618	1.1131	2.2771	1.1228	2.1989	57
4	1.0952	2.4522	1.1040	2.3603	1.1132	2.2757	1.1230	2.1977	56
5	1.0953	2.4506	1.1041	2.3588	1.1134	2.2744	1.1231	2.1964	55
6	1.0955	2.4490	1.1043	2.3574	1.1135	2.2730	1.1233	2.1952	54
7	1.0956	2.4474	1.1044	2.3559	1.1137	2.2717	1.1235	2.1939	53
8	1.0958	2.4458	1.1046	2.3544	1.1139	2.2703	1.1237	2.1927	52
9	1.0959	2.4442	1.1047	2.3530	1.1140	2.2690	1.1238	2.1914	51
10	1.0961	2.4426	1.1049	2.3515	1.1142	2.2676	1.1240	2.1902	50
11	1.0962	2.4411	1.1050	2.3501	1.1143	2.2663	1.1242	2.1889	49
12	1.0963	2.4395	1.1052	2.3486	1.1145	2.2650	1.1243	2.1877	48
13	1.0965	2.4379	1.1053	2.3472	1.1147	2.2636	1.1245	2.1865	47
14	1.0966	2.4363	1.1055	2.3457	1.1148	2.2623	1.1247	2.1852	46
15	1.0968	2.4347	1.1056	2.3443	1.1150	2.2610	1.1248	2.1840	45
16	1.0969	2.4332	1.1058	2.3428	1.1151	2.2596	1.1250	2.1828	44
17	1.0971	2.4316	1.1059	2.3414	1.1153	2.2583	1.1252	2.1815	43
18	1.0972	2.4300	1.1061	2.3399	1.1155	2.2570	1.1253	2.1803	42
19	1.0973	2.4285	1.1062	2.3385	1.1156	2.2556	1.1255	2.1791	41
20	1.0975	2.4269	1.1064	2.3371	1.1158	2.2543	1.1257	2.1778	40
21	1.0976	2.4254	1.1065	2.3356	1.1159	2.2530	1.1258	2.1766	39
22	1.0978	2.4238	1.1067	2.3342	1.1161	2.2517	1.1260	2.1754	38
23	1.0979	2.4222	1.1068	2.3328	1.1163	2.2503	1.1262	2.1742	37
24	1.0981	2.4207	1.1070	2.3313	1.1164	2.2490	1.1264	2.1730	36
25	1.0982	2.4191	1.1072	2.3299	1.1166	2.2477	1.1265	2.1717	35
26	1.0984	2.4176	1.1073	2.3285	1.1167	2.2464	1.1267	2.1705	34
27	1.0985	2.4160	1.1075	2.3271	1.1169	2.2451	1.1269	2.1693	33
28	1.0986	2.4145	1.1076	2.3256	1.1171	2.2438	1.1270	2.1681	32
29	1.0988	2.4130	1.1078	2.3242	1.1172	2.2425	1.1272	2.1669	31
30	1.0989	2.4114	1.1079	2.3228	1.1174	2.2411	1.1274	2.1657	30
31	1.0991	2.4099	1.1081	2.3214	1.1176	2.2398	1.1275	2.1645	29
32	1.0992	2.4083	1.1082	2.3200	1.1177	2.2385	1.1277	2.1633	28
33	1.0994	2.4068	1.1084	2.3186	1.1179	2.2372	1.1279	2.1620	27
34	1.0995	2.4053	1.1085	2.3172	1.1180	2.2359	1.1281	2.1608	26
35	1.0997	2.4037	1.1087	2.3158	1.1182	2.2346	1.1282	2.1596	25
36	1.0998	2.4022	1.1088	2.3143	1.1184	2.2333	1.1284	2.1584	24
37	1.1000	2.4007	1.1090	2.3129	1.1185	2.2320	1.1286	2.1572	23
38	1.1001	2.3992	1.1092	2.3115	1.1187	2.2307	1.1287	2.1560	22
39	1.1003	2.3976	1.1093	2.3101	1.1189	2.2294	1.1289	2.1548	21
40	1.1004	2.3961	1.1095	2.3087	1.1190	2.2282	1.1291	2.1536	20
41	1.1005	2.3946	1.1096	2.3073	1.1192	2.2269	1.1293	2.1525	19
42	1.1007	2.3931	1.1098	2.3059	1.1193	2.2256	1.1294	2.1513	18
43	1.1008	2.3916	1.1099	2.3046	1.1195	2.2243	1.1296	2.1501	17
44	1.1010	2.3901	1.1101	2.3032	1.1197	2.2230	1.1298	2.1489	16
45	1.1011	2.3886	1.1102	2.3018	1.1198	2.2217	1.1299	2.1477	15
46	1.1013	2.3871	1.1104	2.3004	1.1200	2.2204	1.1301	2.1465	14
47	1.1014	2.3856	1.1106	2.2990	1.1202	2.2192	1.1303	2.1453	13
48	1.1016	2.3841	1.1107	2.2976	1.1203	2.2179	1.1305	2.1441	12
49	1.1017	2.3826	1.1109	2.2962	1.1205	2.2166	1.1306	2.1430	11
50	1.1019	2.3811	1.1110	2.2949	1.1207	2.2153	1.1308	2.1418	10
51	1.1020	2.3796	1.1112	2.2935	1.1208	2.2141	1.1310	2.1406	9
52	1.1022	2.3781	1.1113	2.2921	1.1210	2.2128	1.1312	2.1394	8
53	1.1023	2.3766	1.1115	2.2907	1.1212	2.2115	1.1313	2.1382	7
54	1.1025	2.3751	1.1116	2.2894	1.1213	2.2103	1.1315	2.1371	6
55	1.1026	2.3736	1.1118	2.2880	1.1215	2.2090	1.1317	2.1359	5
56	1.1028	2.3721	1.1120	2.2866	1.1217	2.2077	1.1319	2.1347	4
57	1.1029	2.3706	1.1121	2.2853	1.1218	2.2065	1.1320	2.1335	3
58	1.1031	2.3691	1.1123	2.2839	1.1220	2.2052	1.1322	2.1324	2
59	1.1032	2.3677	1.1124	2.2825	1.1222	2.2039	1.1324	2.1312	1
60	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	1.1326	2.1300	0
′	65° Co-sec.	65° Sec.	64° Co-sec.	64° Sec.	63° Co-sec.	63° Sec.	62° Co-sec.	62° Sec.	′

′	28° Sec.	28° Co-sec.	29° Sec.	29° Co-sec.	30° Sec.	30° Co-sec.	31° Sec.	31° Co-sec.	′
0	1.1326	2.1300	1.1433	2.0627	1.1547	2.0000	1.1666	1.9416	60
1	1.1327	2.1289	1.1435	2.0616	1.1549	1.9990	1.1668	1.9407	59
2	1.1329	2.1277	1.1437	2.0605	1.1551	1.9980	1.1670	1.9397	58
3	1.1331	2.1266	1.1439	2.0594	1.1553	1.9970	1.1672	1.9388	57
4	1.1333	2.1254	1.1441	2.0583	1.1555	1.9960	1.1674	1.9378	56
5	1.1334	2.1242	1.1443	2.0573	1.1557	1.9950	1.1676	1.9369	55
6	1.1336	2.1231	1.1445	2.0562	1.1559	1.9940	1.1678	1.9360	54
7	1.1338	2.1219	1.1446	2.0551	1.1561	1.9930	1.1681	1.9350	53
8	1.1340	2.1208	1.1448	2.0540	1.1562	1.9920	1.1683	1.9341	52
9	1.1341	2.1196	1.1450	2.0530	1.1564	1.9910	1.1685	1.9332	51
10	1.1343	2.1185	1.1452	2.0519	1.1566	1.9900	1.1687	1.9322	50
11	1.1345	2.1173	1.1454	2.0508	1.1568	1.9890	1.1689	1.9313	49
12	1.1347	2.1162	1.1456	2.0498	1.1570	1.9880	1.1691	1.9304	48
13	1.1349	2.1150	1.1458	2.0487	1.1572	1.9870	1.1693	1.9295	47
14	1.1350	2.1139	1.1459	2.0476	1.1574	1.9860	1.1695	1.9285	46
15	1.1352	2.1127	1.1461	2.0466	1.1576	1.9850	1.1697	1.9276	45
16	1.1354	2.1116	1.1463	2.0455	1.1578	1.9840	1.1699	1.9267	44
17	1.1356	2.1104	1.1465	2.0444	1.1580	1.9830	1.1701	1.9258	43
18	1.1357	2.1093	1.1467	2.0434	1.1582	1.9820	1.1703	1.9248	42
19	1.1359	2.1082	1.1469	2.0423	1.1584	1.9811	1.1705	1.9239	41
20	1.1361	2.1070	1.1471	2.0413	1.1586	1.9801	1.1707	1.9230	40
21	1.1363	2.1059	1.1473	2.0402	1.1588	1.9791	1.1709	1.9221	39
22	1.1365	2.1048	1.1474	2.0392	1.1590	1.9781	1.1712	1.9212	38
23	1.1366	2.1036	1.1476	2.0381	1.1592	1.9771	1.1714	1.9203	37
24	1.1368	2.1025	1.1478	2.0370	1.1594	1.9761	1.1716	1.9193	36
25	1.1370	2.1014	1.1480	2.0360	1.1596	1.9752	1.1718	1.9184	35
26	1.1372	2.1002	1.1482	2.0349	1.1598	1.9742	1.1720	1.9175	34
27	1.1373	2.0991	1.1484	2.0339	1.1600	1.9732	1.1722	1.9166	33
28	1.1375	2.0980	1.1486	2.0329	1.1602	1.9722	1.1724	1.9157	32
29	1.1377	2.0969	1.1488	2.0318	1.1604	1.9713	1.1726	1.9148	31
30	1.1379	2.0957	1.1489	2.0308	1.1606	1.9703	1.1728	1.9139	30
31	1.1381	2.0946	1.1491	2.0297	1.1608	1.9693	1.1730	1.9130	29
32	1.1382	2.0935	1.1493	2.0287	1.1610	1.9683	1.1732	1.9121	28
33	1.1384	2.0924	1.1495	2.0276	1.1612	1.9674	1.1734	1.9112	27
34	1.1386	2.0912	1.1497	2.0266	1.1614	1.9664	1.1737	1.9102	26
35	1.1388	2.0901	1.1499	2.0256	1.1616	1.9654	1.1739	1.9093	25
36	1.1390	2.0890	1.1501	2.0245	1.1618	1.9645	1.1741	1.9084	24
37	1.1391	2.0879	1.1503	2.0235	1.1620	1.9635	1.1743	1.9075	23
38	1.1393	2.0868	1.1505	2.0224	1.1622	1.9625	1.1745	1.9066	22
39	1.1395	2.0857	1.1507	2.0214	1.1624	1.9616	1.1747	1.9057	21
40	1.1397	2.0846	1.1508	2.0204	1.1626	1.9606	1.1749	1.9048	20
41	1.1399	2.0835	1.1510	2.0194	1.1628	1.9596	1.1751	1.9039	19
42	1.1401	2.0824	1.1512	2.0183	1.1630	1.9587	1.1753	1.9030	18
43	1.1402	2.0812	1.1514	2.0173	1.1632	1.9577	1.1756	1.9021	17
44	1.1404	2.0801	1.1516	2.0163	1.1634	1.9568	1.1758	1.9013	16
45	1.1406	2.0790	1.1518	2.0152	1.1636	1.9558	1.1760	1.9004	15
46	1.1408	2.0779	1.1520	2.0142	1.1638	1.9549	1.1762	1.8995	14
47	1.1410	2.0768	1.1522	2.0132	1.1640	1.9539	1.1764	1.8986	13
48	1.1411	2.0757	1.1524	2.0122	1.1642	1.9530	1.1766	1.8977	12
49	1.1413	2.0746	1.1526	2.0111	1.1644	1.9520	1.1768	1.8968	11
50	1.1415	2.0735	1.1528	2.0101	1.1646	1.9510	1.1770	1.8959	10
51	1.1417	2.0725	1.1530	2.0091	1.1648	1.9501	1.1772	1.8950	9
52	1.1419	2.0714	1.1531	2.0081	1.1650	1.9491	1.1775	1.8941	8
53	1.1421	2.0703	1.1533	2.0071	1.1652	1.9482	1.1777	1.8932	7
54	1.1422	2.0692	1.1535	2.0061	1.1654	1.9473	1.1779	1.8924	6
55	1.1424	2.0681	1.1537	2.0050	1.1656	1.9463	1.1781	1.8915	5
56	1.1426	2.0670	1.1539	2.0040	1.1658	1.9454	1.1783	1.8906	4
57	1.1428	2.0659	1.1541	2.0030	1.1660	1.9444	1.1785	1.8897	3
58	1.1430	2.0648	1.1543	2.0020	1.1662	1.9435	1.1787	1.8888	2
59	1.1432	2.0637	1.1545	2.0010	1.1664	1.9425	1.1790	1.8879	1
60	1.1433	2.0627	1.1547	2.0000	1.1666	1.9416	1.1792	1.8871	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	61°		60°		59°		58°		

′	32° Sec.	32° Co-sec.	33° Sec.	33° Co-sec.	34° Sec.	34° Co-sec.	35° Sec.	35° Co-sec.	′
0	1.1792	1.8871	1.1924	1.8361	1.2062	1.7883	1.2208	1.7434	60
1	1.1794	1.8862	1.1926	1.8352	1.2064	1.7875	1.2210	1.7427	59
2	1.1796	1.8853	1.1928	1.8344	1.2067	1.7867	1.2213	1.7420	58
3	1.1798	1.8844	1.1930	1.8336	1.2069	1.7860	1.2215	1.7413	57
4	1.1800	1.8836	1.1933	1.8328	1.2072	1.7852	1.2218	1.7405	56
5	1.1802	1.8827	1.1935	1.8320	1.2074	1.7844	1.2220	1.7398	55
6	1.1805	1.8818	1.1937	1.8311	1.2076	1.7837	1.2223	1.7391	54
7	1.1807	1.8809	1.1939	1.8303	1.2079	1.7829	1.2225	1.7384	53
8	1.1809	1.8801	1.1942	1.8295	1.2081	1.7821	1.2228	1.7377	52
9	1.1811	1.8792	1.1944	1.8287	1.2083	1.7814	1.2230	1.7369	51
10	1.1813	1.8783	1.1946	1.8279	1.2086	1.7806	1.2233	1.7362	50
11	1.1815	1.8785	1.1948	1.8271	1.2088	1.7798	1.2235	1.7355	49
12	1.1818	1.8766	1.1951	1.8263	1.2091	1.7791	1.2238	1.7348	48
13	1.1820	1.8757	1.1953	1.8255	1.2093	1.7783	1.2240	1.7341	47
14	1.1822	1.8749	1.1955	1.8246	1.2095	1.7776	1.2243	1.7334	46
15	1.1824	1.8740	1.1958	1.8238	1.2098	1.7768	1.2245	1.7327	45
16	1.1826	1.8731	1.1960	1.8230	1.2100	1.7760	1.2248	1.7319	44
17	1.1828	1.8723	1.1962	1.8222	1.2103	1.7753	1.2250	1.7312	43
18	1.1831	1.8714	1.1964	1.8214	1.2105	1.7745	1.2253	1.7305	42
19	1.1833	1.8706	1.1967	1.8206	1.2107	1.7738	1.2255	1.7298	41
20	1.1835	1.8697	1.1969	1.8198	1.2110	1.7730	1.2258	1.7291	40
21	1.1837	1.8688	1.1971	1.8190	1.2112	1.7723	1.2260	1.7284	39
22	1.1839	1.8680	1.1974	1.8182	1.2115	1.7715	1.2263	1.7277	38
23	1.1841	1.8671	1.1976	1.8174	1.2117	1.7708	1.2265	1.7270	37
24	1.1844	1.8663	1.1978	1.8166	1.2119	1.7700	1.2268	1.7263	36
25	1.1846	1.8654	1.1980	1.8158	1.2122	1.7693	1.2270	1.7256	35
26	1.1848	1.8646	1.1983	1.8150	1.2124	1.7685	1.2273	1.7249	34
27	1.1850	1.8637	1.1985	1.8142	1.2127	1.7678	1.2276	1.7242	33
28	1.1852	1.8629	1.1987	1.8134	1.2129	1.7670	1.2278	1.7234	32
29	1.1855	1.8620	1.1990	1.8126	1.2132	1.7663	1.2281	1.7227	31
30	1.1857	1.8611	1.1992	1.8118	1.2134	1.7655	1.2283	1.7220	30
31	1.1859	1.8603	1.1994	1.8110	1.2136	1.7648	1.2286	1.7213	29
32	1.1861	1.8595	1.1997	1.8102	1.2139	1.7640	1.2288	1.7206	28
33	1.1863	1.8586	1.1999	1.8094	1.2141	1.7633	1.2291	1.7199	27
34	1.1866	1.8578	1.2001	1.8086	1.2144	1.7625	1.2293	1.7192	26
35	1.1868	1.8569	1.2004	1.8078	1.2146	1.7618	1.2296	1.7185	25
36	1.1870	1.8561	1.2006	1.8070	1.2149	1.7610	1.2298	1.7178	24
37	1.1872	1.8552	1.2008	1.8062	1.2151	1.7603	1.2301	1.7171	23
38	1.1874	1.8544	1.2010	1.8054	1.2153	1.7596	1.2304	1.7164	22
39	1.1877	1.8535	1.2013	1.8047	1.2156	1.7588	1.2306	1.7157	21
40	1.1879	1.8527	1.2015	1.8039	1.2158	1.7581	1.2309	1.7151	20
41	1.1881	1.8519	1.2017	1.8031	1.2161	1.7573	1.2311	1.7144	19
42	1.1883	1.8510	1.2020	1.8023	1.2163	1.7566	1.2314	1.7137	18
43	1.1886	1.8502	1.2022	1.8015	1.2166	1.7559	1.2316	1.7130	17
44	1.1888	1.8493	1.2024	1.8007	1.2168	1.7551	1.2319	1.7123	16
45	1.1890	1.8485	1.2027	1.7999	1.2171	1.7544	1.2322	1.7116	15
46	1.1892	1.8477	1.2029	1.7992	1.2173	1.7537	1.2324	1.7109	14
47	1.1894	1.8468	1.2031	1.7984	1.2175	1.7529	1.2327	1.7102	13
48	1.1897	1.8460	1.2034	1.7976	1.2178	1.7522	1.2329	1.7095	12
49	1.1899	1.8452	1.2036	1.7968	1.2180	1.7514	1.2332	1.7088	11
50	1.1901	1.8443	1.2039	1.7960	1.2183	1.7507	1.2335	1.7081	10
51	1.1903	1.8435	1.2041	1.7953	1.2185	1.7500	1.2337	1.7075	9
52	1.1906	1.8427	1.2043	1.7945	1.2188	1.7493	1.2340	1.7068	8
53	1.1908	1.8418	1.2046	1.7937	1.2190	1.7485	1.2342	1.7061	7
54	1.1910	1.8410	1.2048	1.7929	1.2193	1.7478	1.2345	1.7054	6
55	1.1912	1.8402	1.2050	1.7921	1.2195	1.7471	1.2348	1.7047	5
56	1.1915	1.8394	1.2053	1.7914	1.2198	1.7463	1.2350	1.7040	4
57	1.1917	1.8385	1.2055	1.7906	1.2200	1.7456	1.2353	1.7033	3
58	1.1919	1.8377	1.2057	1.7898	1.2203	1.7449	1.2355	1.7027	2
59	1.1921	1.8369	1.2060	1.7891	1.2205	1.7442	1.2358	1.7020	1
60	1.1922	1.8361	1.2062	1.7883	1.2208	1.7434	1.2361	1.7013	0
′	Co-sec. 57°	Sec. 57°	Co-sec. 56°	Sec. 56°	Co-sec. 55°	Sec. 55°	Co-sec. 54°	Sec. 54°	′

	36°		37°		38°		39°		
′	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	′
0	1.2361	1.7013	1.2521	1.6616	1.2690	1.6243	1.2867	1.5890	60
1	1.2363	1.7006	1.2524	1.6610	1.2693	1.6237	1.2871	1.5884	59
2	1.2366	1.6999	1.2527	1.6603	1.2696	1.6231	1.2874	1.5879	58
3	1.2368	1.6993	1.2530	1.6597	1.2699	1.6224	1.2877	1.5873	57
4	1.2371	1.6986	1.2532	1.6591	1.2702	1.6218	1.2880	1.5867	56
5	1.2374	1.6979	1.2535	1.6584	1.2705	1.6212	1.2883	1.5862	55
6	1.2376	1.6972	1.2538	1.6578	1.2707	1.6206	1.2886	1.5856	54
7	1.2379	1.6965	1.2541	1.6572	1.2710	1.6200	1.2889	1.5850	53
8	1.2382	1.6959	1.2543	1.6565	1.2713	1.6194	1.2892	1.5845	52
9	1.2384	1.6952	1.2546	1.6559	1.2716	1.6188	1.2895	1.5839	51
10	1.2387	1.6945	1.2549	1.6552	1.2719	1.6182	1.2898	1.5833	50
11	1.2389	1.6938	1.2552	1.6546	1.2722	1.6176	1.2901	1.5828	49
12	1.2392	1.6932	1.2554	1.6540	1.2725	1.6170	1.2904	1.5822	48
13	1.2395	1.6925	1.2557	1.6533	1.2728	1.6164	1.2907	1.5816	47
14	1.2397	1.6918	1.2560	1.6527	1.2731	1.6159	1.2910	1.5811	46
15	1.2400	1.6912	1.2563	1.6521	1.2734	1.6153	1.2913	1.5805	45
16	1.2403	1.6905	1.2565	1.6514	1.2737	1.6147	1.2916	1.5799	44
17	1.2405	1.6898	1.2568	1.6508	1.2739	1.6141	1.2919	1.5794	43
18	1.2408	1.6891	1.2571	1.6502	1.2742	1.6135	1.2922	1.5788	42
19	1.2411	1.6885	1.2574	1.6496	1.2745	1.6129	1.2926	1.5783	41
20	1.2413	1.6878	1.2577	1.6489	1.2748	1.6123	1.2929	1.5777	40
21	1.2416	1.6871	1.2579	1.6483	1.2751	1.6117	1.2932	1.5771	39
22	1.2419	1.6865	1.2582	1.6477	1.2754	1.6111	1.2935	1.5766	38
23	1.2421	1.6858	1.2585	1.6470	1.2757	1.6105	1.2938	1.5760	37
24	1.2424	1.6851	1.2588	1.6464	1.2760	1.6099	1.2941	1.5755	36
25	1.2427	1.6845	1.2591	1.6458	1.2763	1.6093	1.2944	1.5749	35
26	1.2429	1.6838	1.2593	1.6452	1.2766	1.6087	1.2947	1.5743	34
27	1.2432	1.6831	1.2596	1.6445	1.2769	1.6081	1.2950	1.5738	33
28	1.2435	1.6825	1.2599	1.6439	1.2772	1.6077	1.2953	1.5732	32
29	1.2437	1.6818	1.2602	1.6433	1.2775	1.6070	1.2956	1.5727	31
30	1.2440	1.6812	1.2605	1.6427	1.2778	1.6064	1.2960	1.5721	30
31	1.2443	1.6805	1.2607	1.6420	1.2781	1.6058	1.2963	1.5716	29
32	1.2445	1.6798	1.2610	1.6414	1.2784	1.6052	1.2966	1.5710	28
33	1.2448	1.6792	1.2613	1.6408	1.2787	1.6046	1.2969	1.5705	27
34	1.2451	1.6785	1.2616	1.6402	1.2790	1.6040	1.2972	1.5699	26
35	1.2453	1.6779	1.2619	1.6396	1.2793	1.6034	1.2975	1.5694	25
36	1.2456	1.6772	1.2622	1.6389	1.2795	1.6029	1.2978	1.5688	24
37	1.2459	1.6766	1.2624	1.6383	1.2798	1.6023	1.2981	1.5683	23
38	1.2461	1.6759	1.2627	1.6377	1.2801	1.6017	1.2985	1.5677	22
39	1.2464	1.6752	1.2630	1.6371	1.2804	1.6011	1.2988	1.5672	21
40	1.2467	1.6746	1.2633	1.6365	1.2807	1.6005	1.2991	1.5666	20
41	1.2470	1.6739	1.2636	1.6359	1.2810	1.6000	1.2994	1.5661	19
42	1.2472	1.6733	1.2639	1.6352	1.2813	1.5994	1.2997	1.5655	18
43	1.2475	1.6726	1.2641	1.6346	1.2816	1.5988	1.3000	1.5650	17
44	1.2478	1.6720	1.2644	1.6340	1.2819	1.5982	1.3003	1.5644	16
45	1.2480	1.6713	1.2647	1.6334	1.2822	1.5976	1.3006	1.5639	15
46	1.2483	1.6707	1.2650	1.6328	1.2825	1.5971	1.3010	1.5633	14
47	1.2486	1.6700	1.2653	1.6322	1.2828	1.5965	1.3013	1.5628	13
48	1.2488	1.6694	1.2656	1.6316	1.2831	1.5959	1.3016	1.5622	12
49	1.2490	1.6687	1.2659	1.6309	1.2834	1.5953	1.3019	1.5617	11
50	1.2494	1.6681	1.2661	1.6303	1.2837	1.5947	1.3022	1.5611	10
51	1.2497	1.6674	1.2664	1.6297	1.2840	1.5942	1.3025	1.5606	9
52	1.2499	1.6668	1.2667	1.6291	1.2843	1.5936	1.3029	1.5600	8
53	1.2502	1.6661	1.2670	1.6285	1.2846	1.5930	1.3032	1.5595	7
54	1.2505	1.6655	1.2673	1.6279	1.2849	1.5924	1.3035	1.5590	6
55	1.2508	1.6648	1.2676	1.6273	1.2852	1.5919	1.3038	1.5584	5
56	1.2510	1.6642	1.2679	1.6267	1.2855	1.5913	1.3041	1.5579	4
57	1.2513	1.6636	1.2681	1.6261	1.2858	1.5907	1.3044	1.5573	3
58	1.2516	1.6629	1.2684	1.6255	1.2861	1.5901	1.3048	1.5568	2
59	1.2519	1.6623	1.2687	1.6249	1.2864	1.5896	1.3051	1.5563	1
60	1.2521	1.6616	1.2690	1.6243	1.2867	1.5890	1.3054	1.5557	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	53°		52°		51°		50°		

′	40°		41°		42°		43°		′
	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	
0	1.3054	1.5557	1.3250	1.5242	1.3456	1.4945	1.3673	1.4663	60
1	1.3057	1.5552	1.3253	1.5237	1.3460	1.4940	1.3677	1.4658	59
2	1.3060	1.5546	1.3257	1.5232	1.3463	1.4935	1.3681	1.4654	58
3	1.3064	1.5541	1.3260	1.5227	1.3467	1.4930	1.3684	1.4649	57
4	1.3067	1.5536	1.3263	1.5222	1.3470	1.4925	1.3688	1.4644	56
5	1.3070	1.5530	1.3267	1.5217	1.3474	1.4921	1.3692	1.4640	55
6	1.3073	1.5525	1.3270	1.5212	1.3477	1.4916	1.3695	1.4635	54
7	1.3076	1.5520	1.3274	1.5207	1.3481	1.4911	1.3699	1.4631	53
8	1.3080	1.5514	1.3277	1.5202	1.3485	1.4906	1.3703	1.4626	52
9	1.3083	1.5509	1.3280	1.5197	1.3488	1.4901	1.3707	1.4622	51
10	1.3086	1.5503	1.3284	1.5192	1.3492	1.4897	1.3710	1.4617	50
11	1.3089	1.5498	1.3287	1.5187	1.3495	1.4892	1.3714	1.4613	49
12	1.3092	1.5493	1.3290	1.5182	1.3499	1.4887	1.3718	1.4608	48
13	1.3096	1.5487	1.3294	1.5177	1.3502	1.4882	1.3722	1.4604	47
14	1.3099	1.5482	1.3297	1.5171	1.3506	1.4877	1.3725	1.4599	46
15	1.3102	1.5477	1.3301	1.5166	1.3509	1.4873	1.3729	1.4595	45
16	1.3105	1.5471	1.3304	1.5161	1.3513	1.4868	1.3733	1.4590	44
17	1.3109	1.5466	1.3307	1.5156	1.3517	1.4863	1.3737	1.4586	43
18	1.3112	1.5461	1.3311	1.5151	1.3520	1.4858	1.3740	1.4581	42
19	1.3115	1.5456	1.3314	1.5146	1.3524	1.4854	1.3744	1.4577	41
20	1.3118	1.5450	1.3318	1.5141	1.3527	1.4849	1.3748	1.4572	40
21	1.3121	1.5445	1.3321	1.5136	1.3531	1.4844	1.3752	1.4568	39
22	1.3125	1.5440	1.3324	1.5131	1.3534	1.4839	1.3756	1.4563	38
23	1.3128	1.5434	1.3328	1.5126	1.3538	1.4835	1.3759	1.4559	37
24	1.3131	1.5429	1.3331	1.5121	1.3542	1.4830	1.3763	1.4554	36
25	1.3134	1.5424	1.3335	1.5116	1.3545	1.4825	1.3767	1.4550	35
26	1.3138	1.5419	1.3338	1.5111	1.3549	1.4821	1.3771	1.4545	34
27	1.3141	1.5413	1.3342	1.5106	1.3552	1.4816	1.3774	1.4541	33
28	1.3144	1.5408	1.3345	1.5101	1.3556	1.4811	1.3778	1.4536	32
29	1.3148	1.5403	1.3348	1.5096	1.3560	1.4806	1.3782	1.4532	31
30	1.3151	1.5398	1.3352	1.5092	1.3563	1.4802	1.3786	1.4527	30
31	1.3154	1.5392	1.3355	1.5087	1.3567	1.4797	1.3790	1.4523	29
32	1.3157	1.5387	1.3359	1.5082	1.3571	1.4792	1.3794	1.4518	28
33	1.3161	1.5382	1.3362	1.5077	1.3574	1.4788	1.3797	1.4514	27
34	1.3164	1.5377	1.3366	1.5072	1.3578	1.4783	1.3801	1.4510	26
35	1.3167	1.5371	1.3369	1.5067	1.3581	1.4778	1.3805	1.4505	25
36	1.3170	1.5366	1.3372	1.5062	1.3585	1.4774	1.3809	1.4501	24
37	1.3174	1.5361	1.3376	1.5057	1.3589	1.4769	1.3813	1.4496	23
38	1.3177	1.5356	1.3379	1.5052	1.3592	1.4764	1.3816	1.4492	22
39	1.3180	1.5351	1.3383	1.5047	1.3596	1.4760	1.3820	1.4487	21
40	1.3184	1.5345	1.3386	1.5042	1.3600	1.4755	1.3824	1.4483	20
41	1.3187	1.5340	1.3390	1.5037	1.3603	1.4750	1.3828	1.4479	19
42	1.3190	1.5335	1.3393	1.5032	1.3607	1.4746	1.3832	1.4474	18
43	1.3193	1.5330	1.3397	1.5027	1.3611	1.4741	1.3836	1.4470	17
44	1.3197	1.5325	1.3400	1.5022	1.3614	1.4736	1.3839	1.4465	16
45	1.3200	1.5319	1.3404	1.5018	1.3618	1.4732	1.3843	1.4461	15
46	1.3203	1.5314	1.3407	1.5013	1.3622	1.4727	1.3847	1.4457	14
47	1.3207	1.5309	1.3411	1.5008	1.3625	1.4723	1.3851	1.4452	13
48	1.3210	1.5304	1.3414	1.5003	1.3629	1.4718	1.3855	1.4448	12
49	1.3213	1.5299	1.3418	1.4998	1.3633	1.4713	1.3859	1.4443	11
50	1.3217	1.5294	1.3421	1.4993	1.3636	1.4709	1.3863	1.4439	10
51	1.3220	1.5289	1.3425	1.4988	1.3640	1.4704	1.3867	1.4435	9
52	1.3223	1.5283	1.3428	1.4983	1.3644	1.4699	1.3870	1.4430	8
53	1.3227	1.5278	1.3432	1.4979	1.3647	1.4695	1.3874	1.4426	7
54	1.3230	1.5273	1.3435	1.4974	1.3651	1.4690	1.3878	1.4422	6
55	1.3233	1.5268	1.3439	1.4969	1.3655	1.4686	1.3882	1.4417	5
56	1.3237	1.5263	1.3442	1.4964	1.3658	1.4681	1.3886	1.4413	4
57	1.3240	1.5258	1.3446	1.4959	1.3662	1.4676	1.3890	1.4408	3
58	1.3243	1.5253	1.3449	1.4954	1.3666	1.4672	1.3894	1.4404	2
59	1.3247	1.5248	1.3453	1.4949	1.3669	1.4667	1.3898	1.4400	1
60	1.3250	1.5242	1.3456	1.4945	1.3673	1.4663	1.3902	1.4395	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	49°		48°		47°		46°		

′	44° Sec.	44° Co-sec.	′
0	1.3902	1.4395	60
1	1.3905	1.4391	59
2	1.3909	1.4387	58
3	1.3913	1.4382	57
4	1.3917	1.4378	56
5	1.3921	1.4374	55
6	1.3925	1.4370	54
7	1.3929	1.4365	53
8	1.3933	1.4361	52
9	1.3937	1.4357	51
10	1.3941	1.4352	50
11	1.3945	1.4348	49
12	1.3949	1.4344	48
13	1.3953	1.4339	47
14	1.3957	1.4335	46
15	1.3960	1.4331	45
16	1.3964	1.4327	44
17	1.3968	1.4322	43
18	1.3972	1.4318	42
19	1.3976	1.4314	41
20	1.3980	1.4310	40
′	Co-sec. 45°	Sec. 45°	′

′	44° Sec.	44° Co-sec.	′
21	1.3984	1.4305	39
22	1.3988	1.4301	38
23	1.3992	1.4297	37
24	1.3996	1.4292	36
25	1.4000	1.4288	35
26	1.4004	1.4284	34
27	1.4008	1.4280	33
28	1.4012	1.4276	32
29	1.4016	1.4271	31
30	1.4020	1.4267	30
31	1.4024	1.4263	29
32	1.4028	1.4259	28
33	1.4032	1.4254	27
34	1.4036	1.4250	26
35	1.4040	1.4246	25
36	1.4044	1.4242	24
37	1.4048	1.4238	23
38	1.4052	1.4233	22
39	1.4056	1.4229	21
40	1.4060	1.4225	20
′	Co-sec. 45°	Sec. 45°	′

′	44° Sec	44° Co-sec.	′
41	1.4065	1.4221	19
42	1.4069	1.4217	18
43	1.4073	1.4212	17
44	1.4077	1.4208	16
45	1.4081	1.4204	15
46	1.4085	1.4200	14
47	1.4089	1.4196	13
48	1.4093	1.4192	12
49	1.4097	1.4188	11
50	1.4101	1.4183	10
51	1.4105	1.4179	9
52	1.4109	1.4175	8
53	1.4113	1.4171	7
54	1.4117	1.4167	6
55	1.4122	1.4163	5
56	1.4126	1.4159	4
57	1.4130	1.4154	3
58	1.4134	1.4150	2
59	1.4138	1.4146	1
60	1.4142	1.4142	0
′	Co-sec. 45°	Sec 45°	′

Table 61

N.	0	1	2	3	4	5	6	7	8	9	Diff.
100	000000	0434	0868	1301	1734	2166	2598	3029	3461	3891	432
101	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
102	8600	9026	9451	9876	*0300	*0724	*1147	*1570	*1993	*2415	424
103	012837	3259	3680	4100	4521	4940	5360	5779	6197	6616	420
104	7033	7451	7868	8284	8700	9116	9532	9947	*0361	*0775	416
105	021189	1603	2016	2428	2841	3252	3664	4075	4486	4896	412
106	5306	5715	6125	6533	6942	7350	7757	8164	8571	8978	408
107	9384	9789	*0195	*0600	*1004	*1408	*1812	*2216	*2619	*3021	404
108	033424	3826	4227	4628	5029	5430	5830	6230	6629	7028	400
109	7426	7825	8223	8620	9017	9414	9811	*0207	*0602	*0998	397

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	434	43	87	130	174	217	260	304	347	391	434
	433	43	87	130	173	217	260	303	346	390	433
	432	43	86	130	173	216	259	302	346	389	432
	431	43	86	129	172	216	259	302	345	388	431
	430	43	86	129	172	215	258	301	344	387	430
	429	43	86	129	172	215	257	300	343	386	429
	428	43	86	128	171	214	257	300	342	385	428
	427	43	85	128	171	214	256	299	342	384	427
	426	43	85	128	170	213	256	298	341	383	426
	425	43	85	128	170	213	255	298	340	383	425
	424	42	85	127	170	212	254	297	339	382	424
	423	42	85	127	169	212	254	296	338	381	423
	422	42	84	127	169	211	253	295	338	380	422
	421	42	84	126	168	211	253	295	337	379	421
	420	42	84	126	168	210	252	294	336	378	420
	419	42	84	126	168	210	251	293	335	377	419
	418	42	84	125	167	209	251	293	334	376	418
	417	42	83	125	167	209	250	292	334	375	417
	416	42	83	125	166	208	250	291	333	374	416
	415	42	83	125	166	208	249	291	332	374	415
	414	41	83	124	166	207	248	290	331	373	414
	413	41	83	124	165	207	248	289	330	372	413
	412	41	82	124	165	206	247	288	330	371	412
	411	41	82	123	164	206	247	288	329	370	411
	410	41	82	123	164	205	246	287	328	369	410
	409	41	82	123	164	205	245	286	327	368	409
	408	41	82	122	163	204	245	286	326	367	408
	407	41	81	122	163	204	244	285	326	366	407
	406	41	81	122	162	203	244	284	325	365	406
	405	41	81	122	162	203	243	284	324	365	405
	404	40	81	121	162	202	242	283	323	364	404
	403	40	81	121	161	202	242	282	322	363	403
	402	40	80	121	161	201	241	281	322	362	402
	401	40	80	120	160	201	241	281	321	361	401
	400	40	80	120	160	200	240	280	320	360	400
	399	40	80	120	160	200	239	279	319	359	399
	398	40	80	119	159	199	239	279	318	358	398
	397	40	79	119	159	199	238	278	318	357	397
	396	40	79	119	158	198	238	277	317	356	396
	395	40	79	119	158	198	237	277	316	356	395
	394	39	79	118	158	197	236	276	315	355	394
	393	39	79	118	157	197	236	275	314	354	393
	392	39	78	118	157	196	235	274	314	353	392
	391	39	78	117	156	196	235	274	313	352	391
	390	39	78	117	156	195	234	273	312	351	390
	389	39	78	117	156	195	233	272	311	350	389
	388	39	78	116	155	194	233	272	310	349	388
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
110	041393	1787	2182	2576	2969	3362	3755	4148	4540	4932	393
111	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
112	9218	9606	9993	*0380	*0766	*1153	*1538	*1924	*2309	*2694	386
113	053078	3463	3846	4230	4613	4996	5378	5760	6142	6524	383
114	6905	7286	7666	8046	8426	8805	9185	9563	9942	*0320	379
115	060698	1075	1452	1829	2206	2582	2958	3333	3709	4083	376
116	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	373
117	8186	8557	8928	9298	9668	*0038	*0407	*0776	*1145	*1514	370
118	071882	2250	2617	2985	3352	3718	4085	4451	4816	5182	366
119	5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363
120	079181	9543	9904	*0266	*0626	*0987	*1347	*1707	*2067	*2426	360
121	082785	3144	3503	3861	4219	4576	4934	5291	5647	6004	357
122	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
123	9905	*0258	*0611	*0963	*1315	*1667	*2018	*2370	*2721	*3071	352
124	093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	387	39	77	116	155	194	232	271	310	348	387
	386	39	77	116	154	193	232	270	309	347	386
	385	39	77	116	154	193	231	270	308	347	385
	384	38	77	115	154	192	230	269	307	346	384
	383	38	77	115	153	192	230	268	306	345	383
	382	38	76	115	153	191	229	267	306	344	382
	381	38	76	114	152	191	229	267	305	343	381
	380	38	76	114	152	190	228	266	304	342	380
	379	38	76	114	152	190	227	265	303	341	379
	378	38	76	113	151	189	227	265	302	340	378
	377	38	75	113	151	189	226	264	302	339	377
	376	38	75	113	150	188	226	263	301	338	376
	375	38	75	113	150	188	225	263	300	338	375
	374	37	75	112	150	187	224	262	299	337	374
	373	37	75	112	149	187	224	261	298	336	373
	372	37	74	112	149	186	223	260	298	335	372
	371	37	74	111	148	186	223	260	297	334	371
	370	37	74	111	148	185	222	259	296	333	370
	369	37	74	111	148	185	221	258	295	332	369
	368	37	74	110	147	184	221	258	294	331	368
	367	37	73	110	147	184	220	257	294	330	367
	366	37	73	110	146	183	220	256	293	329	366
	365	37	73	110	146	183	219	256	292	329	365
	364	36	73	109	146	182	218	255	291	328	364
	363	36	73	109	145	182	218	254	290	327	363
	362	36	72	109	145	181	217	253	290	326	362
	361	36	72	108	144	181	217	253	289	325	361
	360	36	72	108	144	180	216	252	288	324	360
	359	36	72	108	144	180	215	251	287	323	359
	358	36	72	107	143	179	215	251	286	322	358
	357	36	71	107	143	179	214	250	286	321	357
	356	36	71	107	142	178	214	249	285	320	356
	355	36	71	107	142	178	213	249	284	320	355
	354	35	71	106	142	177	212	248	283	319	354
	353	35	71	106	141	177	212	247	282	318	353
	352	35	70	106	141	176	211	246	282	317	352
	351	35	70	105	140	176	211	246	281	316	351
	350	35	70	105	140	175	210	245	280	315	350
	349	35	70	105	140	175	209	244	279	314	349
	348	35	70	104	139	174	209	244	278	313	348
	347	35	69	104	139	174	208	243	278	312	347
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
125	096910	7257	7604	7951	8298	8644	8990	9335	9681	*0026	346
126	100371	0715	1059	1403	1747	2091	2434	2777	3119	3462	343
127	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	341
128	7210	7549	7888	8227	8565	8903	9241	9579	9916	*0253	338
129	110590	0926	1263	1599	1934	2270	2605	2940	3275	3609	335
130	113943	4277	4611	4944	5278	5611	5943	6276	6608	6940	333
131	7271	7603	7934	8265	8595	8926	9256	9586	9915	*0245	330
132	120574	0903	1231	1560	1888	2216	2544	2871	3198	3525	328
133	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
134	7105	7429	7753	8076	8399	8722	9045	9368	9690	*0012	323
135	130334	0655	0977	1298	1619	1939	2260	2580	2900	3219	321
136	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
137	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
138	9879	*0194	*0508	*0822	*1136	*1450	*1763	*2076	*2389	*2702	314
139	143015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	347	35	69	104	139	174	208	243	278	312	347
	346	35	69	104	138	173	208	242	277	311	346
	345	35	69	104	138	173	207	242	276	311	345
	344	34	69	103	138	172	206	241	275	310	344
	343	34	69	103	137	172	206	240	274	309	343
	342	34	68	103	137	171	205	239	274	308	342
	341	34	68	102	136	171	205	239	273	307	341
	340	34	68	102	136	170	204	238	272	306	340
	339	34	68	102	136	170	203	237	271	305	339
	338	34	68	101	135	169	203	237	270	304	338
	337	34	67	101	135	169	202	236	270	303	337
	336	34	67	101	134	168	202	235	269	302	336
	335	34	67	101	134	168	201	235	268	302	335
	334	33	67	100	134	167	200	234	267	301	334
	333	33	67	100	133	167	200	233	266	300	333
	332	33	66	100	133	166	199	232	266	299	332
	331	33	66	99	132	166	199	232	265	298	331
	330	33	66	99	132	165	198	231	264	297	330
	329	33	66	99	132	165	197	230	263	296	329
	328	33	66	98	131	164	197	230	262	295	328
	327	33	65	98	131	164	196	229	262	294	327
	326	33	65	98	130	163	196	228	261	293	326
	325	33	65	98	130	163	195	228	260	293	325
	324	32	65	97	130	162	194	227	259	292	324
	323	32	65	97	129	162	194	226	258	291	323
	322	32	64	97	129	161	193	225	258	290	322
	321	32	64	96	128	161	193	225	257	289	321
	320	32	64	96	128	160	192	224	256	288	320
	319	32	64	96	128	160	191	223	255	287	319
	318	32	64	95	127	159	191	223	254	286	318
	317	32	63	95	127	159	190	222	254	285	317
	316	32	63	95	126	158	190	221	253	284	316
	315	32	63	95	126	158	189	221	252	284	315
	314	31	63	94	126	157	188	220	251	283	314
	313	31	63	94	125	157	188	219	250	282	313
	312	31	62	94	125	156	187	218	250	281	312
	311	31	62	93	124	156	187	218	249	280	311
	310	31	62	93	124	155	186	217	248	279	310
	309	31	62	93	124	155	185	216	247	278	309
	308	31	62	92	123	154	185	216	246	277	308
	307	31	61	92	123	154	184	215	246	276	307
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
140	146128	6438	6748	7058	7367	7676	7985	8294	8603	8911	309
141	9219	9527	9835	*0142	*0449	*0756	*1063	*1370	*1676	*1982	307
142	152288	2594	2900	3205	3510	3815	4120	4424	4728	5032	305
143	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
144	8362	8664	8965	9266	9567	9868	*0168	*0469	*0769	*1068	301
145	161368	1667	1967	2266	2564	2863	3161	3460	3758	4055	299
146	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
147	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
148	170262	0555	0848	1141	1434	1726	2019	2311	2603	2895	293
149	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291
150	176091	6381	6670	6959	7248	7536	7825	8113	8401	8689	289
151	8977	9264	9552	9839	*0126	*0413	*0699	*0986	*1272	*1558	287
152	181844	2129	2415	2700	2985	3270	3555	3839	4123	4407	285
153	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
154	7521	7803	8084	8366	8647	8928	9209	9490	9771	*0051	281
155	190332	0612	0892	1171	1451	1730	2010	2289	2567	2846	279
156	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
157	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
158	8657	8932	9206	9481	9755	*0029	*0303	*0577	*0850	*1124	274
159	201397	1670	1943	2216	2488	2761	3033	3305	3577	3848	272

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	306	31	61	92	122	153	184	214	245	275	306
	305	31	61	92	122	153	183	214	244	275	305
	304	30	61	91	122	152	182	213	243	274	304
	303	30	61	91	121	152	182	212	242	273	303
	302	30	60	91	121	151	181	211	242	272	302
	301	30	60	90	120	151	181	211	241	271	301
	300	30	60	90	120	150	180	210	240	270	300
	299	30	60	90	120	150	179	209	239	269	299
	298	30	60	89	119	149	179	209	238	268	298
	297	30	59	89	119	149	178	208	238	267	297
	296	30	59	89	118	148	178	207	237	266	296
	295	30	59	89	118	148	177	207	236	266	295
	294	29	59	88	118	147	176	206	235	265	294
	293	29	59	88	117	147	176	205	234	264	293
	292	29	58	88	117	146	175	204	234	263	292
	291	29	58	87	116	146	175	204	233	262	291
	290	29	58	87	116	145	174	203	232	261	290
	289	29	58	87	116	145	173	202	231	260	289
	288	29	58	86	115	144	173	202	230	259	288
	287	29	57	86	115	144	172	201	230	258	287
	286	29	57	86	114	143	172	200	229	257	286
	285	29	57	86	114	143	171	200	228	257	285
	284	28	57	85	114	142	170	199	227	256	284
	283	28	57	85	113	142	170	198	226	255	283
	282	28	56	85	113	141	169	197	226	254	282
	281	28	56	84	112	141	169	197	225	253	281
	280	28	56	84	112	140	168	196	224	252	280
	279	28	56	84	112	140	167	195	223	251	279
	278	28	56	83	111	139	167	195	222	250	278
	277	28	55	83	111	139	166	194	222	249	277
	276	28	55	83	110	138	166	193	221	248	276
	275	28	55	83	110	138	165	193	220	248	275
	274	27	55	82	110	137	164	192	219	247	274
	273	27	55	82	109	137	164	191	218	246	273
	272	27	54	82	109	136	163	190	218	245	272
	271	27	54	81	108	136	163	190	217	244	271
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
160	204120	4391	4663	4934	5204	5475	5746	6016	6286	6556	271
161	6826	7096	7365	7634	7904	8173	8441	8710	8979	9247	269
162	9515	9783	*0051	*0319	*0586	*0853	*1121	*1388	*1654	*1921	267
163	212188	2454	2720	2986	3252	3518	3783	4049	4314	4579	266
164	4844	5109	5373	5638	5902	6166	6430	6694	6957	7221	264
165	217484	7747	8010	8273	8536	8798	9060	9323	9585	9846	262
166	220108	0370	0631	0892	1153	1414	1675	1936	2196	2456	261
167	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
168	5309	5568	5826	6084	6342	6600	6858	7115	7372	7630	258
169	7887	8144	8400	8657	8913	9170	9426	9682	9938	*0193	256
170	230449	0704	0960	1215	1470	1724	1979	2234	2488	2742	255
171	2996	3250	3504	3757	4011	4264	4517	4770	5023	5276	253
172	5528	5781	6033	6285	6537	6789	7041	7292	7544	7795	252
173	8046	8297	8548	8799	9049	9299	9550	9800	*0050	*0300	250
174	240549	0799	1048	1297	1546	1795	2044	2293	2541	2790	249
175	243038	3286	3534	3782	4030	4277	4525	4772	5019	5266	248
176	5513	5759	6006	6252	6499	6745	6991	7237	7482	7728	246
177	7973	8219	8464	8709	8954	9198	9443	9687	9932	*0176	245
178	250420	0664	0908	1151	1395	1638	1881	2125	2368	2610	243
179	2853	3096	3338	3580	3822	4064	4306	4548	4790	5031	242

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	272	27	54	82	109	136	163	190	218	245	272
	271	27	54	81	108	136	163	190	217	244	271
	270	27	54	81	108	135	162	189	216	243	270
	269	27	54	81	108	135	161	188	215	242	269
	268	27	54	80	107	134	161	188	214	241	268
	267	27	53	80	107	134	160	187	214	240	267
	266	27	53	80	106	133	160	186	213	239	266
	265	27	53	80	106	133	159	186	212	239	265
	264	26	53	79	106	132	158	185	211	238	264
	263	26	53	79	105	132	158	184	210	237	263
	262	26	52	79	105	131	157	183	210	236	262
	261	26	52	78	104	131	157	183	209	235	261
	260	26	52	78	104	130	156	182	208	234	260
	259	26	52	78	104	130	155	181	207	233	259
	258	26	52	77	103	129	155	181	206	232	258
	257	26	51	77	103	129	154	180	206	231	257
	256	26	51	77	102	128	154	179	205	230	256
	255	26	51	77	102	128	153	179	204	230	255
	254	25	51	76	102	127	152	178	203	229	254
	253	25	51	76	101	127	152	177	202	228	253
	252	25	50	76	101	126	151	176	202	227	252
	251	25	50	75	100	126	151	176	201	226	251
	250	25	50	75	100	125	150	175	200	225	250
	249	25	50	75	100	125	149	174	199	224	249
	248	25	50	74	99	124	149	174	198	223	248
	247	25	49	74	99	124	148	173	198	222	247
	246	25	49	74	98	123	148	172	197	221	246
	245	25	49	74	98	123	147	172	196	221	245
	244	24	49	73	98	122	146	171	195	220	244
	243	24	49	73	97	122	146	170	194	219	243
	242	24	48	73	97	121	145	169	194	218	242
	241	24	48	72	96	121	145	169	193	217	241
	240	24	48	72	96	120	144	168	192	216	240
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
180	255273	5514	5755	5996	6237	6477	6718	6958	7198	7439	241
181	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
182	260071	0310	0548	0787	1025	1263	1501	1739	1976	2214	238
183	2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	237
184	4818	5054	5290	5525	5761	5996	6232	6467	6702	6937	235
185	267172	7406	7641	7875	8110	8344	8578	8812	9046	9279	234
186	9513	9746	9980	*0213	*0446	*0679	*0912	*1144	*1377	*1609	233
187	271842	2074	2306	2538	2770	3001	3233	3464	3696	3927	232
188	4158	4389	4620	4850	5081	5311	5542	5772	6002	6232	230
189	6462	6692	6921	7151	7380	7609	7838	8067	8296	8525	229
190	278754	8982	9211	9439	9667	9895	*0123	*0351	*0578	*0806	228
191	281033	1261	1488	1715	1942	2169	2396	2622	2849	3075	227
192	3301	3527	3753	3979	4205	4431	4656	4882	5107	5332	226
193	5557	5782	6007	6232	6456	6681	6905	7130	7354	7578	225
194	7802	8026	8249	8473	8696	8920	9143	9366	9589	9812	223
195	290035	0257	0480	0702	0925	1147	1369	1591	1813	2034	222
196	2256	2478	2699	2920	3141	3363	3584	3804	4025	4246	221
197	4466	4687	4907	5127	5347	5567	5787	6007	6226	6446	220
198	6665	6884	7104	7323	7542	7761	7979	8198	8416	8635	219
199	8853	9071	9289	9507	9725	9943	*0161	*0378	*0595	*0813	218
200	301030	1247	1464	1681	1898	2114	2331	2547	2764	2980	217
201	3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
202	5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
203	7496	7710	7924	8137	8351	8564	8778	8991	9204	9417	213
204	9630	9843	*0056	*0268	*0481	*0693	*0906	*1118	*1330	*1542	212

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	239	24	48	72	96	120	143	167	191	215	239
	238	24	48	71	95	119	143	167	190	214	238
	237	24	47	71	95	119	142	166	190	213	237
	236	24	47	71	94	118	142	165	189	212	236
	235	24	47	71	94	118	141	165	188	212	235
	234	23	47	70	94	117	140	164	187	211	234
	233	23	47	70	93	117	140	163	186	210	233
	232	23	46	70	93	116	139	162	186	209	232
	231	23	46	69	92	116	139	162	185	208	231
	230	23	46	69	92	115	138	161	184	207	230
	229	23	46	69	92	115	137	160	183	206	229
	228	23	46	68	91	114	137	160	182	205	228
	227	23	45	68	91	114	136	159	182	204	227
	226	23	45	68	90	113	136	158	181	203	226
	225	23	45	68	90	113	135	158	180	203	225
	224	22	45	67	90	112	134	157	179	202	224
	223	22	45	67	89	112	134	156	178	201	223
	222	22	44	67	89	111	133	155	178	200	222
	221	22	44	66	88	111	133	155	177	199	221
	220	22	44	66	88	110	132	154	176	198	220
	219	22	44	66	88	110	131	153	175	197	219
	218	22	44	65	87	109	131	153	174	196	218
	217	22	43	65	87	109	130	152	174	195	217
	216	22	43	65	86	108	130	151	173	194	216
	215	22	43	65	86	108	129	151	172	194	215
	214	21	43	64	86	107	128	150	171	193	214
	213	21	43	64	85	107	128	149	170	192	213
	212	21	42	64	85	106	127	148	170	191	212
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
205	311754	1966	2177	2389	2600	2812	3023	3234	3445	3656	211
206	3867	4078	4289	4499	4710	4920	5130	5340	5551	5760	210
207	5970	6180	6390	6599	6809	7018	7227	7436	7646	7854	209
208	8063	8272	8481	8689	8898	9106	9314	9522	9730	9938	208
209	320146	0354	0562	0769	0977	1184	1391	1598	1805	2012	207
210	322219	2426	2633	2839	3046	3252	3458	3665	3871	4077	206
211	4282	4488	4694	4899	5105	5310	5516	5721	5926	6131	205
212	6336	6541	6745	6950	7155	7359	7563	7767	7972	8176	204
213	8380	8583	8787	8991	9194	9398	9601	9805	*0008	*0211	203
214	330414	0617	0819	1022	1225	1427	1630	1832	2034	2236	202
215	332438	2640	2842	3044	3246	3447	3649	3850	4051	4253	202
216	4454	4655	4856	5057	5257	5458	5658	5859	6059	6260	201
217	6460	6660	6860	7060	7260	7459	7659	7858	8058	8257	200
218	8456	8656	8855	9054	9253	9451	9650	9849	*0047	*0246	199
219	340444	0642	0841	1039	1237	1435	1632	1830	2028	2225	198
220	342423	2620	2817	3014	3212	3409	3606	3802	3999	4196	197
221	4392	4589	4785	4981	5178	5374	5570	5766	5962	6157	196
222	6353	6549	6744	6939	7135	7330	7525	7720	7915	8110	195
223	8305	8500	8694	8889	9083	9278	9472	9666	9860	*0054	194
224	350248	0442	0636	0829	1023	1216	1410	1603	1796	1989	193
225	352183	2375	2568	2761	2954	3147	3339	3532	3724	3916	193
226	4108	4301	4493	4685	4876	5068	5260	5452	5643	5834	192
227	6026	6217	6408	6599	6790	6981	7172	7363	7554	7744	191
228	7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	190
229	9835	*0025	*0215	*0404	*0593	*0783	*0972	*1161	*1350	*1539	189
230	361728	1917	2105	2294	2482	2671	2859	3048	3236	3424	188
231	3612	3800	3988	4176	4363	4551	4739	4926	5113	5301	188
232	5488	5675	5862	6049	6236	6423	6610	6796	6983	7169	187
233	7356	7542	7729	7915	8101	8287	8473	8659	8845	9030	186
234	9216	9401	9587	9772	9958	*0143	*0328	*0513	*0698	*0883	185

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	212	21	42	64	85	106	127	148	170	191	212
	211	21	42	63	84	106	127	148	169	190	211
	210	21	42	63	84	105	126	147	168	189	210
	209	21	42	63	84	105	125	146	167	188	209
	208	21	42	62	83	104	125	146	166	187	208
	207	21	41	62	83	104	124	145	166	186	207
	206	21	41	62	82	103	124	144	165	185	206
	205	21	41	62	82	103	123	144	164	185	205
	204	20	41	61	82	102	122	143	163	184	204
	203	20	41	61	81	102	122	142	162	183	203
	202	20	40	61	81	101	121	141	162	182	202
	201	20	40	60	80	101	121	141	161	181	201
	200	20	40	60	80	100	120	140	160	180	200
	199	20	40	60	80	100	119	139	159	179	199
	198	20	40	59	79	99	119	139	158	178	198
	197	20	39	59	79	99	118	138	158	177	197
	196	20	39	59	78	98	118	137	157	176	196
	195	20	39	59	78	98	117	137	156	176	195
	194	19	39	58	78	97	116	136	155	175	194
	193	19	39	58	77	97	116	135	154	174	193
	192	19	38	58	77	96	115	134	154	173	192
	191	19	38	57	76	96	115	134	153	172	191
	190	19	38	57	76	95	114	133	152	171	190
	189	19	38	57	76	95	113	132	151	170	189
	188	19	38	56	75	94	113	132	150	169	188
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
235	371068	1253	1437	1622	1806	1991	2175	2360	2544	2728	184
236	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
237	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
238	6577	6759	6942	7124	7306	7488	7670	7852	8034	8216	182
239	8398	8580	8761	8943	9124	9306	9487	9668	9849	*0030	181
240	380211	0392	0573	0754	0934	1115	1296	1476	1656	1837	181
241	2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	180
242	3815	3995	4174	4353	4533	4712	4891	5070	5249	5428	179
243	5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	178
244	7390	7568	7746	7923	8101	8279	8456	8634	8811	8989	178
245	389166	9343	9520	9698	9875	*0051	*0228	*0405	*0582	*0759	177
246	390935	1112	1288	1464	1641	1817	1993	2169	2345	2521	176
247	2697	2873	3048	3224	3400	3575	3751	3926	4101	4277	176
248	4452	4627	4802	4977	5152	5326	5501	5676	5850	6025	175
249	6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
250	397940	8114	8287	8461	8634	8808	8981	9154	9328	9501	173
251	9674	9847	*0020	*0192	*0365	*0538	*0711	*0883	*1056	*1228	173
252	401401	1573	1745	1917	2089	2261	2433	2605	2777	2949	172
253	3121	3292	3464	3635	3807	3978	4149	4320	4492	4663	171
254	4834	5005	5176	5346	5517	5688	5858	6029	6199	6370	171
255	406540	6710	6881	7051	7221	7391	7561	7731	7901	8070	170
256	8240	8410	8579	8749	8918	9087	9257	9426	9595	9764	169
257	9933	*0102	*0271	*0440	*0609	*0777	*0946	*1114	*1283	*1451	169
258	411620	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
259	3300	3467	3635	3803	3970	4137	4305	4472	4639	4806	167
260	414973	5140	5307	5474	5641	5808	5974	6141	6308	6474	167
261	6641	6807	6973	7139	7306	7472	7638	7804	7970	8135	166
262	8301	8467	8633	8798	8964	9129	9295	9460	9625	9791	165
263	9956	*0121	*0286	*0451	*0616	*0781	*0945	*1110	*1275	*1439	165
264	421604	1768	1933	2097	2261	2426	2590	2754	2918	3082	164

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	187	19	37	56	75	94	112	131	150	168	187
	186	19	37	56	74	93	112	130	149	167	186
	185	19	37	56	74	93	111	130	148	167	185
	184	18	37	55	74	92	110	129	147	166	184
	183	18	37	55	73	92	110	128	146	165	183
	182	18	36	55	73	91	109	127	146	164	182
	181	18	36	54	72	91	109	127	145	163	181
	180	18	36	54	72	90	108	126	144	162	180
	179	18	36	54	72	90	107	125	143	161	179
	178	18	36	53	71	89	107	125	142	160	178
	177	18	35	53	71	89	106	124	142	159	177
	176	18	35	53	70	88	106	123	141	158	176
	175	18	35	53	70	88	105	123	140	158	175
	174	17	35	52	70	87	104	122	139	157	174
	173	17	35	52	69	87	104	121	138	156	173
	172	17	34	52	69	86	103	120	138	155	172
	171	17	34	51	68	86	103	120	137	154	171
	170	17	34	51	68	85	102	119	136	153	170
	169	17	34	51	68	85	101	118	135	152	169
	168	17	34	50	67	84	101	118	134	151	168
	167	17	33	50	67	84	100	117	134	150	167
	166	17	33	50	66	83	100	116	133	149	166
	165	17	33	50	66	83	99	116	132	149	165
	164	16	33	49	66	82	98	115	131	148	164
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
265	423246	3410	3574	3737	3901	4065	4228	4392	4555	4718	164
266	4882	5045	5208	5371	5534	5697	5860	6023	6186	6349	163
267	6511	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
268	8135	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
269	9752	9914	*0075	*0236	*0398	*0559	*0720	*0881	*1042	*1203	161
270	431364	1525	1685	1846	2007	2167	2328	2488	2649	2809	161
271	2969	3130	3290	3450	3610	3770	3930	4090	4249	4409	160
272	4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
273	6163	6322	6481	6640	6799	6957	7116	7275	7433	7592	159
274	7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
275	439333	9491	9648	9806	9964	*0122	*0279	*0437	*0594	*0752	158
276	440909	1066	1224	1381	1538	1695	1852	2009	2166	2323	157
277	2480	2637	2793	2950	3106	3263	3419	3576	3732	3889	157
278	4045	4201	4357	4513	4669	4825	4981	5137	5293	5449	156
279	5604	5760	5915	6071	6226	6382	6537	6692	6848	7003	155
280	447158	7313	7468	7623	7778	7933	8088	8242	8397	8552	155
281	8706	8861	9015	9170	9324	9478	9633	9787	9941	*0095	154
282	450249	0403	0557	0711	0865	1018	1172	1326	1479	1633	154
283	1786	1940	2093	2247	2400	2553	2706	2859	3012	3165	153
284	3318	3471	3624	3777	3930	4082	4235	4387	4540	4692	153
285	454845	4997	5150	5302	5454	5606	5758	5910	6062	6214	152
286	6366	6518	6670	6821	6973	7125	7276	7428	7579	7731	152
287	7882	8033	8184	8336	8487	8638	8789	8940	9091	9242	151
288	9392	9543	9694	9845	9995	*0146	*0296	*0447	*0597	*0748	151
289	460898	1048	1198	1348	1499	1649	1799	1948	2098	2248	150
290	462398	2548	2697	2847	2997	3146	3296	3445	3594	3744	150
291	3893	4042	4191	4340	4490	4639	4788	4936	5085	5234	149
292	5383	5532	5680	5829	5977	6126	6274	6423	6571	6719	149
293	6868	7016	7164	7312	7460	7608	7756	7904	8052	8200	148
294	8347	8495	8643	8790	8938	9085	9233	9380	9527	9675	148
295	469822	9969	*0116	*0263	*0410	*0557	*0704	*0851	*0998	*1145	147
296	471292	1438	1585	1732	1878	2025	2171	2318	2464	2610	146
297	2756	2903	3049	3195	3341	3487	3633	3779	3925	4071	146
298	4216	4362	4508	4653	4799	4944	5090	5235	5381	5526	146
299	5671	5816	5962	6107	6252	6397	6542	6687	6832	6976	145

PROPORTIONAL PARTS

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
	164	16	33	49	66	82	98	115	131	148	164
	163	16	33	49	65	82	98	114	130	147	163
	162	16	32	49	65	81	97	113	130	146	162
	161	16	32	48	64	81	97	113	129	145	161
	160	16	32	48	64	80	96	112	128	144	160
	159	16	32	48	64	80	95	111	127	143	159
	158	16	32	47	63	79	95	111	126	142	158
	157	16	31	47	63	79	94	110	126	141	157
	156	16	31	47	62	78	94	109	125	140	156
	155	16	31	47	62	78	93	109	124	140	155
	154	15	31	46	62	77	92	108	123	139	154
	153	15	31	46	61	77	92	107	122	138	153
	152	15	30	46	61	76	91	106	122	137	152
	151	15	30	45	60	76	91	106	121	136	151
	150	15	30	45	60	75	90	105	120	135	150
	149	15	30	45	60	75	89	104	119	134	149
	148	15	30	44	59	74	89	104	118	133	148
	147	15	29	44	59	74	88	103	118	132	147
	146	15	29	44	58	73	88	102	117	131	146
	145	15	29	44	58	73	87	102	116	131	145
	144	14	29	43	58	72	86	101	115	130	144
	143	14	29	43	57	72	86	100	114	129	143
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
300	477121	7266	7411	7555	7700	7844	7989	8133	8278	8422	145
301	8566	8711	8855	8999	9143	9287	9431	9575	9719	9863	144
302	480007	0151	0294	0438	0582	0725	0869	1012	1156	1299	144
303	1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
304	2874	3016	3159	3302	3445	3587	3730	3872	4015	4157	143
305	484300	4442	4585	4727	4869	5011	5153	5295	5437	5579	142
306	5721	5863	6005	6147	6289	6430	6572	6714	6855	6997	142
307	7138	7280	7421	7563	7704	7845	7986	8127	8269	8410	141
308	8551	8692	8833	8974	9114	9255	9396	9537	9677	9818	141
309	9958	*0099	*0239	*0380	*0520	*0661	*0801	*0941	*1081	*1222	140
310	491362	1502	1642	1782	1922	2062	2201	2341	2481	2621	140
311	2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
312	4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
313	5544	5683	5822	5960	6099	6238	6376	6515	6653	6791	139
314	6930	7068	7206	7344	7483	7621	7759	7897	8035	8173	138
315	498311	8448	8586	8724	8862	8999	9137	9275	9412	9550	138
316	9687	9824	9962	*0099	*0236	*0374	*0511	*0648	*0785	*0922	137
317	501059	1196	1333	1470	1607	1744	1880	2017	2154	2291	137
318	2427	2564	2700	2837	2973	3109	3246	3382	3518	3655	136
319	3791	3927	4063	4199	4335	4471	4607	4743	4878	5014	136
320	505150	5286	5421	5557	5693	5828	5964	6099	6234	6370	136
321	6505	6640	6776	6911	7046	7181	7316	7451	7586	7721	135
322	7856	7991	8126	8260	8395	8530	8664	8799	8934	9068	135
323	9203	9337	9471	9606	9740	9874	*0009	*0143	*0277	*0411	134
324	510545	0679	0813	0947	1081	1215	1349	1482	1616	1750	134
325	511883	2017	2151	2284	2418	2551	2684	2818	2951	3084	133
326	3218	3351	3484	3617	3750	3883	4016	4149	4282	4415	133
327	4548	4681	4813	4946	5079	5211	5344	5476	5609	5741	133
328	5874	6006	6139	6271	6403	6535	6668	6800	6932	7064	132
329	7196	7328	7460	7592	7724	7855	7987	8119	8251	8382	132
330	518514	8646	8777	8909	9040	9171	9303	9434	9566	9697	131
331	9828	9959	*0090	*0221	*0353	*0484	*0615	*0745	*0876	*1007	131
332	521138	1269	1400	1530	1661	1792	1922	2053	2183	2314	131
333	2444	2575	2705	2835	2966	3096	3226	3356	3486	3616	130
334	3746	3876	4006	4136	4266	4396	4526	4656	4785	4915	130
335	525045	5174	5304	5434	5563	5693	5822	5951	6081	6210	129
336	6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
337	7630	7759	7888	8016	8145	8274	8402	8531	8660	8788	129
338	8917	9045	9174	9302	9430	9559	9687	9815	9943	*0072	128
339	530200	0328	0456	0584	0712	0840	0968	1096	1223	1351	128

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROPORTIONAL PARTS	142	14	28	43	57	71	85	99	114	128	142
	141	14	28	42	56	71	85	99	113	127	141
	140	14	28	42	56	70	84	98	112	126	140
	139	14	28	42	56	70	83	97	111	125	139
	138	14	28	41	55	69	83	97	110	124	138
	137	14	27	41	55	69	82	96	110	123	137
	136	14	27	41	54	68	82	95	109	122	136
	135	14	27	41	54	68	81	95	108	122	135
	134	13	27	40	54	67	80	94	107	121	134
	133	13	27	40	53	67	80	93	106	120	133
	132	13	26	40	53	66	79	92	106	119	132
	131	13	26	39	52	66	79	92	105	118	131
	130	13	26	39	52	65	78	91	104	117	130
	129	13	26	39	52	65	77	90	103	116	129
	128	13	26	38	51	64	77	90	102	115	128
	127	13	25	38	51	64	76	89	102	114	127
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
340	531479	1607	1734	1862	1990	2117	2245	2372	2500	2627	128
341	2754	2882	3009	3136	3264	3391	3518	3645	3772	3899	127
342	4026	4153	4280	4407	4534	4661	4787	4914	5041	5167	127
343	5294	5421	5547	5674	5800	5927	6053	6180	6306	6432	126
344	6558	6685	6811	6937	7063	7189	7315	7441	7567	7693	126
345	537819	7945	8071	8197	8322	8448	8574	8699	8825	8951	126
346	9076	9202	9327	9452	9578	9703	9829	9954	*0079	*0204	125
347	540329	0455	0580	0705	0830	0955	1080	1205	1330	1454	125
348	1579	1704	1829	1953	2078	2203	2327	2452	2576	2701	125
349	2825	2950	3074	3199	3323	3447	3571	3696	3820	3944	124
350	544068	4192	4316	4440	4564	4688	4812	4936	5060	5183	124
351	5307	5431	5555	5678	5802	5925	6049	6172	6296	6419	124
352	6543	6666	6789	6913	7036	7159	7282	7405	7529	7652	123
353	7775	7898	8021	8144	8267	8389	8512	8635	8758	8881	123
354	9003	9126	9249	9371	9494	9616	9739	9861	9984	*0106	123
355	550228	0351	0473	0595	0717	0840	0962	1084	1206	1328	122
356	1450	1572	1694	1816	1938	2060	2181	2303	2425	2547	122
357	2668	2790	2911	3033	3155	3276	3398	3519	3640	3762	121
358	3883	4004	4126	4247	4368	4489	4610	4731	4852	4973	121
359	5094	5215	5336	5457	5578	5699	5820	5940	6061	6182	121
360	556303	6423	6544	6664	6785	6905	7026	7146	7267	7387	120
361	7507	7627	7748	7868	7988	8108	8228	8349	8469	8589	120
362	8709	8829	8948	9068	9188	9308	9428	9548	9667	9787	120
363	9907	*0026	*0146	*0265	*0385	*0504	*0624	*0743	*0863	*0982	119
364	561101	1221	1340	1459	1578	1698	1817	1936	2055	2174	119
365	562293	2412	2531	2650	2769	2887	3006	3125	3244	3362	119
366	3481	3600	3718	3837	3955	4074	4192	4311	4429	4548	119
367	4666	4784	4903	5021	5139	5257	5376	5494	5612	5730	118
368	5848	5966	6084	6202	6320	6437	6555	6673	6791	6909	118
369	7026	7144	7262	7379	7497	7614	7732	7849	7967	8084	118
370	568202	8319	8436	8554	8671	8788	8905	9023	9140	9257	117
371	9374	9491	9608	9725	9842	9959	*0076	*0193	*0309	*0426	117
372	570543	0660	0776	0893	1010	1126	1243	1359	1476	1592	117
373	1709	1825	1942	2058	2174	2291	2407	2523	2639	2755	116
374	2872	2988	3104	3220	3336	3452	3568	3684	3800	3915	116
375	574031	4147	4263	4379	4494	4610	4726	4841	4957	5072	116
376	5188	5303	5419	5534	5650	5765	5880	5996	6111	6226	115
377	6341	6457	6572	6687	6802	6917	7032	7147	7262	7377	115
378	7492	7607	7722	7836	7951	8066	8181	8295	8410	8525	115
379	8639	8754	8868	8983	9097	9212	9326	9441	9555	9669	114

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROP. PARTS	128	13	26	38	51	64	77	90	102	115	128
	127	13	25	38	51	64	76	89	102	114	127
	126	13	25	38	50	63	76	88	101	113	126
	125	13	25	38	50	63	75	88	100	113	125
	124	12	25	37	50	62	74	87	99	112	124
	123	12	25	37	49	62	74	86	98	111	123
	122	12	24	37	49	61	73	85	98	110	122
	121	12	24	36	48	61	73	85	97	109	121
	120	12	24	36	48	60	72	84	96	108	120
	119	12	24	36	48	60	71	83	95	107	119
	118	12	24	35	47	59	71	83	94	106	118
	117	12	23	35	47	59	70	82	94	105	117
	116	12	23	35	46	58	70	81	93	104	116
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
380	579784	9898	*0012	*0126	*0241	*0355	*0469	*0583	*0697	*0811	114
381	580925	1039	1153	1267	1381	1495	1608	1722	1836	1950	114
382	2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	114
383	3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	113
384	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
385	585461	5574	5686	5799	5912	6024	6137	6250	6362	6475	113
386	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	112
387	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
388	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	112
389	9950	*0061	*0173	*0284	*0396	*0507	*0619	*0730	*0842	*0953	112
390	591065	1176	1287	1399	1510	1621	1732	1843	1955	2066	111
391	2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
392	3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	111
393	4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	110
394	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	110
395	596597	6707	6817	6927	7037	7146	7256	7366	7476	7586	110
396	7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	110
397	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	109
398	9883	9992	*0101	*0210	*0319	*0428	*0537	*0646	*0755	*0864	109
399	600973	1082	1191	1299	1408	1517	1625	1734	1843	1951	109
400	602060	2169	2277	2386	2494	2603	2711	2819	2928	3036	108
401	3144	3253	3361	3469	3577	3686	3794	3902	4010	4118	108
402	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	108
403	5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	108
404	6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	107
405	607455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
406	8526	8633	8740	8847	8954	9061	9167	9274	9381	9488	107
407	9594	9701	9808	9914	*0021	*0128	*0234	*0341	*0447	*0554	107
408	610660	0767	0873	0979	1086	1192	1298	1405	1511	1617	106
409	1723	1829	1936	2042	2148	2254	2360	2466	2572	2678	106
410	612784	2890	2996	3102	3207	3313	3419	3525	3630	3736	106
411	3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	106
412	4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	105
413	5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
414	7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	105
415	618048	8153	8257	8362	8466	8571	8676	8780	8884	8989	105
416	9093	9198	9302	9406	9511	9615	9719	9824	9928	*0032	104
417	620136	0240	0344	0448	0552	0656	0760	0864	0968	1072	104
418	1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	104
419	2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	104

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROP. PARTS	115	12	23	35	46	58	69	81	92	104	115
	114	11	23	34	46	57	68	80	91	103	114
	113	11	23	34	45	57	68	79	90	102	113
	112	11	22	34	45	56	67	78	90	101	112
	111	11	22	33	44	56	67	78	89	100	111
	110	11	22	33	44	55	66	77	88	99	110
	109	11	22	33	44	55	65	76	87	98	109
	108	11	22	32	43	54	65	76	86	97	108
	107	11	21	32	43	54	64	75	86	96	107
	106	11	21	32	42	53	64	74	85	95	106
	105	11	21	32	42	53	63	74	84	95	105
	104	10	21	31	42	52	62	73	83	94	104
	103	10	21	31	41	52	62	72	82	93	103
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
420	623249	3353	3456	3559	3663	3766	3869	3973	4076	4179	103
421	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	103
422	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	103
423	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	103
424	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	102
425	628389	8491	8593	8695	8797	8900	9002	9104	9206	9308	102
426	9410	9512	9613	9715	9817	9919	*0021	*0123	*0224	*0326	102
427	630428	0530	0631	0733	0835	0936	1038	1139	1241	1342	102
428	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	101
429	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	101
430	633468	3569	3670	3771	3872	3973	4074	4175	4276	4376	101
431	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	101
432	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	100
433	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	100
434	7490	7590	7690	7790	7890	7990	8090	8190	8290	8389	100
435	638489	8589	8689	8789	8888	8988	9088	9188	9287	9387	100
436	9486	9586	9686	9785	9885	9984	*0084	*0183	*0283	*0382	99
437	640481	0581	0680	0779	0879	0978	1077	1177	1276	1375	99
438	1474	1573	1672	1771	1871	1970	2069	2168	2267	2366	99
439	2465	2563	2662	2761	2860	2959	3058	3156	3255	3354	99
440	643453	3551	3650	3749	3847	3946	4044	4143	4242	4340	98
441	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	98
442	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	98
443	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	98
444	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	98
445	648360	8458	8555	8653	8750	8848	8945	9043	9140	9237	97
446	9335	9432	9530	9627	9724	9821	9919	*0016	*0113	*0210	97
447	650308	0405	0502	0599	0696	0793	0890	0987	1084	1181	97
448	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	97
449	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	97
450	653213	3309	3405	3502	3598	3695	3791	3888	3984	4080	96
451	4177	4273	4369	4465	4562	4658	4754	4850	4946	5042	96
452	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	96
453	6098	6194	6290	6386	6482	6577	6673	6769	6864	6960	96
454	7056	7152	7247	7343	7438	7534	7629	7725	7820	7916	96
455	658011	8107	8202	8298	8393	8488	8584	8679	8774	8870	95
456	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	95
457	9916	*0011	*0106	*0201	*0296	*0391	*0486	*0581	*0676	*0771	95
458	660865	0960	1055	1150	1245	1339	1434	1529	1623	1718	95
459	1813	1907	2002	2096	2191	2286	2380	2475	2569	2663	95
460	662758	2852	2947	3041	3135	3230	3324	3418	3512	3607	94
461	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	94
462	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
463	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	94
464	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	94

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROP. PARTS	104	10	21	31	42	52	62	73	83	94	104
	103	10	21	31	41	52	62	72	82	93	103
	102	10	20	31	41	51	61	71	82	92	102
	101	10	20	30	40	51	61	71	81	91	101
	100	10	20	30	40	50	60	70	80	90	100
	99	10	20	30	40	50	59	69	79	89	99
	98	10	20	29	39	49	59	69	78	88	98
	97	10	19	29	39	49	58	68	78	87	97
	96	10	19	29	38	48	58	67	77	86	96
	95	10	19	29	38	48	57	67	76	86	95
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
465	667453	7546	7640	7733	7826	7920	8013	8106	8199	8293	93
466	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	93
467	9317	9410	9503	9596	9689	9782	9875	9967	*0060	*0153	93
468	670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	93
469	1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	93
470	672098	2190	2283	2375	2467	2560	2652	2744	2836	2929	92
471	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	92
472	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
473	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	92
474	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	92
475	676694	6785	6876	6968	7059	7151	7242	7333	7424	7516	91
476	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	91
477	8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
478	9428	9519	9610	9700	9791	9882	9973	*0063	*0154	*0245	91
479	680336	0426	0517	0607	0698	0789	0879	0970	1060	1151	91
480	681241	1332	1422	1513	1603	1693	1784	1874	1964	2055	90
481	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	90
482	3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
483	3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	90
484	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	90
485	685742	5831	5921	6010	6100	6189	6279	6368	6458	6547	89
486	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	89
487	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
488	8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	89
489	9309	9398	9486	9575	9664	9753	9841	9930	*0019	*0107	89
490	690196	0285	0373	0462	0550	0639	0728	0816	0905	0993	89
491	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	88
492	1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	88
493	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
494	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	88
495	694605	4693	4781	4868	4956	5044	5131	5219	5307	5394	88
496	5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	87
497	6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	87
498	7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	87
499	8101	8188	8275	8362	8449	8535	8622	8709	8796	8883	87
500	698970	9057	9144	9231	9317	9404	9491	9578	9664	9751	87
501	9838	9924	*0011	*0098	*0184	*0271	*0358	*0444	*0531	*0617	87
502	700704	0790	0877	0963	1050	1136	1222	1309	1395	1482	86
503	1568	1654	1741	1827	1913	1999	2086	2172	2258	2344	86
504	2431	2517	2603	2689	2775	2861	2947	3033	3119	3205	86
505	703291	3377	3463	3549	3635	3721	3807	3893	3979	4065	86
506	4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	86
507	5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	86
508	5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	85
509	6718	6803	6888	6974	7059	7144	7229	7315	7400	7485	85

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROP. PARTS	94	9	19	28	38	47	56	66	75	85	94
	93	9	19	28	37	47	56	65	74	84	93
	92	9	18	28	37	46	55	64	74	83	92
	91	9	18	27	36	46	55	64	73	82	91
	90	9	18	27	36	45	54	63	72	81	90
	89	9	18	27	36	45	53	62	71	80	89
	88	9	18	26	35	44	53	62	70	79	88
	87	9	17	26	35	44	52	61	70	78	87
	86	9	17	26	34	43	52	60	69	77	86
	85	9	17	26	34	43	51	60	68	77	85
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
510	707570	7655	7740	7826	7911	7996	8081	8166	8251	8336	85
511	8421	8506	8591	8676	8761	8846	8931	9015	9100	9185	85
512	9270	9355	9440	9524	9609	9694	9779	9863	9948	*0033	85
513	710117	0202	0287	0371	0456	0540	0625	0710	0794	0879	85
514	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	84
515	711807	1892	1976	2060	2144	2229	2313	2397	2481	2566	84
516	2650	2734	2818	2902	2986	3070	3154	3238	3323	3407	84
517	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
518	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	84
519	5167	5251	5335	5418	5502	5586	5669	5753	5836	5920	84
520	716003	6087	6170	6254	6337	6421	6504	6588	6671	6754	83
521	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	83
522	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	83
523	8502	8585	8668	8751	8834	8917	9000	9083	9165	9248	83
524	9331	9414	9497	9580	9663	9745	9828	9911	9994	*0077	83
525	720159	0242	0325	0407	0490	0573	0655	0738	0821	0903	83
526	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	82
527	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	82
528	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	82
529	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	724276	4358	4440	4522	4604	4685	4767	4849	4931	5013	82
531	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	82
532	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	82
533	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	81
534	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	81
535	728354	8435	8516	8597	8678	8759	8841	8922	9003	9084	81
536	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
537	9974	*0055	*0136	*0217	*0298	*0378	*0459	*0540	*0621	*0702	81
538	730782	0863	0944	1024	1105	1186	1266	1347	1428	1508	81
539	1589	1669	1750	1830	1911	1991	2072	2152	2233	2313	81
540	732394	2474	2555	2635	2715	2796	2876	2956	3037	3117	80
541	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	80
542	3999	4079	4160	4240	4320	4400	4480	4560	4640	4720	80
543	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	80
544	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	80
545	736397	6476	6556	6635	6715	6795	6874	6954	7034	7113	80
546	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	79
547	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	79
548	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	79
549	9572	9651	9731	9810	9889	9968	*0047	*0126	*0205	*0284	79
550	740363	0442	0521	0600	0678	0757	0836	0915	0994	1073	79
551	1152	1230	1309	1388	1467	1546	1624	1703	1782	1860	79
552	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	79
553	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	78
554	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	78

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PROP. PARTS	86	9	17	26	34	43	52	60	69	77	86
	85	9	17	26	34	43	51	60	68	77	85
	84	8	17	25	34	42	50	59	67	76	84
	83	8	17	25	33	42	50	58	66	75	83
	82	8	16	25	33	41	49	57	66	74	82
	81	8	16	24	32	41	49	57	65	73	81
	80	8	16	24	32	40	48	56	64	72	80
	79	8	16	24	32	40	47	55	63	71	79
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
555	744293	4371	4449	4528	4606	4684	4762	4840	4919	4997	78
556	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
557	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	78
558	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	78
559	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	78
560	748188	8266	8343	8421	8498	8576	8653	8731	8808	8885	77
561	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	77
562	9736	9814	9891	9968	*0045	*0123	*0200	*0277	*0354	*0431	77
563	750508	0586	0663	0740	0817	0894	0971	1048	1125	1202	77
564	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	77
565	752048	2125	2202	2279	2356	2433	2509	2586	2663	2740	77
566	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	77
567	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	77
568	4348	4425	4501	4578	4654	4730	4807	4883	4960	5036	76
569	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	76
570	755875	5951	6027	6103	6180	6256	6332	6408	6484	6560	76
571	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
572	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	76
573	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	76
574	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	76
575	759668	9743	9819	9894	9970	*0045	*0121	*0196	*0272	*0347	75
576	760422	0498	0573	0649	0724	0799	0875	0950	1025	1101	75
577	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	75
578	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	75
579	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353	75
580	763428	3503	3578	3653	3727	3802	3877	3952	4027	4101	75
581	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	75
582	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	75
583	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	74
584	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	74
585	767156	7230	7304	7379	7453	7527	7601	7675	7749	7823	74
586	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
587	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	74
588	9377	9451	9525	9599	9673	9746	9820	9894	9968	*0042	74
589	770115	0189	0263	0336	0410	0484	0557	0631	0705	0778	74
590	770852	0926	0999	1073	1146	1220	1293	1367	1440	1514	74
591	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	73
592	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	73
593	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	73
594	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	73
595	774517	4590	4663	4736	4809	4882	4955	5028	5100	5173	73
596	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	73
597	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	73
598	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	73
599	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	72

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PRO. PARTS	78	8	16	23	31	39	47	55	62	70	78
	77	8	15	23	31	39	46	54	62	69	77
	76	8	15	23	30	38	46	53	61	68	76
	75	8	15	23	30	38	45	53	60	68	75
	74	7	15	22	30	37	44	52	59	67	74
	73	7	15	22	29	37	44	51	58	66	73
	72	7	14	22	29	36	43	50	58	65	72
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
600	778151	8224	8296	8368	8441	8513	8585	8658	8730	8802	72
601	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	72
602	9596	9669	9741	9813	9885	9957	*0029	*0101	*0173	*0245	72
603	780317	0389	0461	0533	0605	0677	0749	0821	0893	0965	72
604	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	72
605	781755	1827	1899	1971	2042	2114	2186	2258	2329	2401	72
606	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	72
607	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	71
608	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	71
609	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	71
610	785330	5401	5472	5543	5615	5686	5757	5828	5899	5970	71
611	6041	6112	6183	6254	6325	6396	6467	6538	6609	6680	71
612	6751	6822	6893	6964	7035	7106	7177	7248	7319	7390	71
613	7460	7531	7602	7673	7744	7815	7885	7956	8027	8098	71
614	8168	8239	8310	8381	8451	8522	8593	8663	8734	8804	71
615	788875	8946	9016	9087	9157	9228	9299	9369	9440	9510	71
616	9581	9651	9722	9792	9863	9933	*0004	*0074	*0144	*0215	70
617	790285	0356	0426	0496	0567	0637	0707	0778	0848	0918	70
618	0988	1059	1129	1199	1269	1340	1410	1480	1550	1620	70
619	1691	1761	1831	1901	1971	2041	2111	2181	2252	2322	70
620	792392	2462	2532	2602	2672	2742	2812	2882	2952	3022	70
621	3092	3162	3231	3301	3371	3441	3511	3581	3651	3721	70
622	3790	3860	3930	4000	4070	4139	4209	4279	4349	4418	70
623	4488	4558	4627	4697	4767	4836	4906	4976	5045	5115	70
624	5185	5254	5324	5393	5463	5532	5602	5672	5741	5811	70
625	795880	5949	6019	6088	6158	6227	6297	6366	6436	6505	69
626	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	69
627	7268	7337	7406	7475	7545	7614	7683	7752	7821	7890	69
628	7960	8029	8098	8167	8236	8305	8374	8443	8513	8582	69
629	8651	8720	8789	8858	8927	8996	9065	9134	9203	9272	69
630	799341	9409	9478	9547	9616	9685	9754	9823	9892	9961	69
631	800029	0098	0167	0236	0305	0373	0442	0511	0580	0648	69
632	0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	69
633	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	69
634	2089	2158	2226	2295	2363	2432	2500	2568	2637	2705	68
635	802774	2842	2910	2979	3047	3116	3184	3252	3321	3389	68
636	3457	3525	3594	3662	3730	3798	3867	3935	4003	4071	68
637	4139	4208	4276	4344	4412	4480	4548	4616	4685	4753	68
638	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
639	5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	68
640	806180	6248	6316	6384	6451	6519	6587	6655	6723	6790	68
641	6858	6926	6994	7061	7129	7197	7264	7332	7400	7467	68
642	7535	7603	7670	7738	7806	7873	7941	8008	8076	8143	68
643	8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	67
644	8886	8953	9021	9088	9156	9223	9290	9358	9425	9492	67
645	809560	9627	9694	9762	9829	9896	9964	*0031	*0098	*0165	67
646	810233	0300	0367	0434	0501	0569	0636	0703	0770	0837	67
647	0904	0971	1039	1106	1173	1240	1307	1374	1441	1508	67
648	1575	1642	1709	1776	1843	1910	1977	2044	2111	2178	67
649	2245	2312	2379	2445	2512	2579	2646	2713	2780	2847	67

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PRO. P'TS	73	7	15	22	29	37	44	51	58	66	73
	72	7	14	22	29	36	43	50	58	65	72
	71	7	14	21	28	36	43	50	57	64	71
	70	7	14	21	28	35	42	49	56	63	70
	69	7	14	21	28	35	41	48	55	62	69
	68	7	14	20	27	34	41	48	54	61	68
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
650	812913	2980	3047	3114	3181	3247	3314	3381	3448	3514	67
651	3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	67
652	4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	67
653	4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	66
654	5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	66
655	816241	6308	6374	6440	6506	6573	6639	6705	6771	6838	66
656	6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	66
657	7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	66
658	8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	66
659	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	819544	9610	9676	9741	9807	9873	9939	*0004	*0070	*0136	66
661	820201	0267	0333	0399	0464	0530	0595	0661	0727	0792	66
662	0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	66
663	1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	65
664	2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	65
665	822822	2887	2952	3018	3083	3148	3213	3279	3344	3409	65
666	3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	65
667	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
668	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
669	5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	65
670	826075	6140	6204	6269	6334	6399	6464	6528	6593	6658	65
671	6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	65
672	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	65
673	8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	64
674	8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	64
675	829304	9368	9432	9497	9561	9625	9690	9754	9818	9882	64
676	9947	*0011	*0075	*0139	*0204	*0268	*0332	*0396	*0460	*0525	64
677	830589	0653	0717	0781	0845	0909	0973	1037	1102	1166	64
678	1230	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
679	1870	1934	1998	2062	2126	2189	2253	2317	2381	2445	64
680	832509	2573	2637	2700	2764	2828	2892	2956	3020	3083	64
681	3147	3211	3275	3338	3402	3466	3530	3593	3657	3721	64
682	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	64
683	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	64
684	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	63
685	835691	5754	5817	5881	5944	6007	6071	6134	6197	6261	63
686	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	63
687	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	63
688	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	63
689	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
690	838849	8912	8975	9038	9101	9164	9227	9289	9352	9415	63
691	9478	9541	9604	9667	9729	9792	9855	9918	9981	*0043	63
692	840106	0169	0232	0294	0357	0420	0482	0545	0608	0671	63
693	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	63
694	1359	1422	1485	1547	1610	1672	1735	1797	1860	1922	63
695	841985	2047	2110	2172	2235	2297	2360	2422	2484	2547	62
696	2609	2672	2734	2796	2859	2921	2983	3046	3108	3170	62
697	3233	3295	3357	3420	3482	3544	3606	3669	3731	3793	62
698	3855	3918	3980	4042	4104	4166	4229	4291	4353	4415	62
699	4477	4539	4601	4664	4726	4788	4850	4912	4974	5036	62

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PRO. P'TS	67	7	13	20	27	34	40	47	54	60	67
	66	7	13	20	26	33	40	46	53	59	66
	65	7	13	20	26	33	39	46	52	59	65
	64	6	13	19	26	32	38	45	51	58	64
	63	6	13	19	25	32	38	44	50	57	63
	62	6	12	19	25	31	37	43	50	56	62
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
700	845098	5160	5222	5284	5346	5408	5470	5532	5594	5656	62
701	5718	5780	5842	5904	5966	6028	6090	6151	6213	6275	62
702	6337	6399	6461	6523	6585	6646	6708	6770	6832	6894	62
703	6955	7017	7079	7141	7202	7264	7326	7388	7449	7511	62
704	7573	7634	7696	7758	7819	7881	7943	8004	8066	8128	62
705	848189	8251	8312	8374	8435	8497	8559	8620	8682	8743	62
706	8805	8866	8928	8989	9051	9112	9174	9235	9297	9358	61
707	9419	9481	9542	9604	9665	9726	9788	9849	9911	9972	61
708	850033	0095	0156	0217	0279	0340	0401	0462	0524	0585	61
709	0646	0707	0769	0830	0891	0952	1014	1075	1136	1197	61
710	851258	1320	1381	1442	1503	1564	1625	1686	1747	1809	61
711	1870	1931	1992	2053	2114	2175	2236	2297	2358	2419	61
712	2480	2541	2602	2663	2724	2785	2846	2907	2968	3029	61
713	3090	3150	3211	3272	3333	3394	3455	3516	3577	3637	61
714	3698	3759	3820	3881	3941	4002	4063	4124	4185	4245	61
715	854306	4367	4428	4488	4549	4610	4670	4731	4792	4852	61
716	4913	4974	5034	5095	5156	5216	5277	5337	5398	5459	61
717	5519	5580	5640	5701	5761	5822	5882	5943	6003	6064	61
718	6124	6185	6245	6306	6366	6427	6487	6548	6608	6668	60
719	6729	6789	6850	6910	6970	7031	7091	7152	7212	7272	60
720	857332	7393	7453	7513	7574	7634	7694	7755	7815	7875	60
721	7935	7995	8056	8116	8176	8236	8297	8357	8417	8477	60
722	8537	8597	8657	8718	8778	8838	8898	8958	9018	9078	60
723	9138	9198	9258	9318	9379	9439	9499	9559	9619	9679	60
724	9739	9799	9859	9918	9978	*0038	*0098	*0158	*0218	*0278	60
725	860338	0398	0458	0518	0578	0637	0697	0757	0817	0877	60
726	0937	0996	1056	1116	1176	1236	1295	1355	1415	1475	60
727	1534	1594	1654	1714	1773	1833	1893	1952	2012	2072	60
728	2131	2191	2251	2310	2370	2430	2489	2549	2608	2668	60
729	2728	2787	2847	2906	2966	3025	3085	3144	3204	3263	60
730	863323	3382	3442	3501	3561	3620	3680	3739	3799	3858	59
731	3917	3977	4036	4096	4155	4214	4274	4333	4392	4452	59
732	4511	4570	4630	4689	4748	4808	4867	4926	4985	5045	59
733	5104	5163	5222	5282	5341	5400	5459	5519	5578	5637	59
734	5696	5755	5814	5874	5933	5992	6051	6110	6169	6228	59
735	866287	6346	6405	6465	6524	6583	6642	6701	6760	6819	59
736	6878	6937	6996	7055	7114	7173	7232	7291	7350	7409	59
737	7467	7526	7585	7644	7703	7762	7821	7880	7939	7998	59
738	8056	8115	8174	8233	8292	8350	8409	8468	8527	8586	59
739	8644	8703	8762	8821	8879	8938	8997	9056	9114	9173	59
740	869232	9290	9349	9408	9466	9525	9584	9642	9701	9760	59
741	9818	9877	9935	9994	*0053	*0111	*0170	*0228	*0287	*0345	59
742	870404	0462	0521	0579	0638	0696	0755	0813	0872	0930	58
743	0989	1047	1106	1164	1223	1281	1339	1398	1456	1515	58
744	1573	1631	1690	1748	1806	1865	1923	1981	2040	2098	58
745	872156	2215	2273	2331	2389	2448	2506	2564	2622	2681	58
746	2739	2797	2855	2913	2972	3030	3088	3146	3204	3262	58
747	3321	3379	3437	3495	3553	3611	3669	3727	3785	3844	58
748	3902	3960	4018	4076	4134	4192	4250	4308	4366	4424	58
749	4482	4540	4598	4656	4714	4772	4830	4888	4945	5003	58

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PRO. P'TS	62	6	12	19	25	31	37	43	50	56	62
	61	6	12	18	24	31	37	43	49	55	61
	60	6	12	18	24	30	36	42	48	54	60
	59	6	12	18	24	30	35	41	47	53	59
	58	6	12	17	23	29	35	41	46	52	58
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
750	875061	5119	5177	5235	5293	5351	5409	5466	5524	5582	58
751	5640	5698	5756	5813	5871	5929	5987	6045	6102	6160	58
752	6218	6276	6333	6391	6449	6507	6564	6622	6680	6737	58
753	6795	6853	6910	6968	7026	7083	7141	7199	7256	7314	58
754	7371	7429	7487	7544	7602	7659	7717	7774	7832	7889	58
755	877947	8004	8062	8119	8177	8234	8292	8349	8407	8464	57
756	8522	8579	8637	8694	8752	8809	8866	8924	8981	9039	57
757	9096	9153	9211	9268	9325	9383	9440	9497	9555	9612	57
758	9669	9726	9784	9841	9898	9956	*0013	*0070	*0127	*0185	57
759	880242	0299	0356	0413	0471	0528	0585	0642	0699	0756	57
760	880814	0871	0928	0985	1042	1099	1156	1213	1271	1328	57
761	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	57
762	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	57
763	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	57
764	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	57
765	883661	3718	3775	3832	3888	3945	4002	4059	4115	4172	57
766	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	57
767	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	57
768	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	57
769	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	56
770	886491	6547	6604	6660	6716	6773	6829	6885	6942	6998	56
771	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	56
772	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	56
773	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	56
774	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	56
775	889302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
776	9862	9918	9974	*0030	*0086	*0141	*0197	*0253	*0309	*0365	56
777	890421	0477	0533	0589	0645	0700	0756	0812	0868	0924	56
778	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	56
779	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	56
780	892095	2150	2206	2262	2317	2373	2429	2484	2540	2595	56
781	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	56
782	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	56
783	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	55
784	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	55
785	894870	4925	4980	5036	5091	5146	5201	5257	5312	5367	55
786	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	55
787	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	55
788	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	55
789	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	897627	7682	7737	7792	7847	7902	7957	8012	8067	8122	55
791	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	55
792	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	55
793	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	55
794	9821	9875	9930	9985	*0039	*0094	*0149	*0203	*0258	*0312	55
795	900367	0422	0476	0531	0586	0640	0695	0749	0804	0859	55
796	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	55
797	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	54
798	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	54
799	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	54

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PR. PTS.	57	6	11	17	23	29	34	40	46	51	57
	56	6	11	17	22	28	34	39	45	50	56
	55	6	11	17	22	28	33	39	44	50	55
	54	5	11	16	22	27	32	38	43	49	54
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
800	903090	3144	3199	3253	3307	3361	3416	3470	3524	3578	54
801	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	54
802	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	54
803	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	54
804	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
805	905796	5850	5904	5958	6012	6066	6119	6173	6227	6281	54
806	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	54
807	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	54
808	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	54
809	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	54
810	908485	8539	8592	8646	8699	8753	8807	8860	8914	8967	54
811	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	54
812	9556	9610	9663	9716	9770	9823	9877	9930	9984	*0037	53
813	910091	0144	0197	0251	0304	0358	0411	0464	0518	0571	53
814	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	53
815	911158	1211	1264	1317	1371	1424	1477	1530	1584	1637	53
816	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	53
817	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	53
818	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	53
819	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	53
820	913814	3867	3920	3973	4026	4079	4132	4184	4237	4290	53
821	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	53
822	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	53
823	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	53
824	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	53
825	916454	6507	6559	6612	6664	6717	6770	6822	6875	6927	53
826	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	53
827	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	52
828	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	52
829	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	52
830	919078	9130	9183	9235	9287	9340	9392	9444	9496	9549	52
831	9601	9653	9706	9758	9810	9862	9914	9967	*0019	*0071	52
832	920123	0176	0228	0280	0332	0384	0436	0489	0541	0593	52
833	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	52
834	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	52
835	921686	1738	1790	1842	1894	1946	1998	2050	2102	2154	52
836	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	52
837	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	52
838	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	52
839	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	52
840	924279	4331	4383	4434	4486	4538	4589	4641	4693	4744	52
841	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	52
842	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	52
843	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	51
844	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	51
845	926857	6908	6959	7011	7062	7114	7165	7216	7268	7319	51
846	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	51
847	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	51
848	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	51
849	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	51

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PR. PTS.	55	6	11	17	22	28	33	39	44	50	55
	54	5	11	16	22	27	32	38	43	49	54
	53	5	11	16	21	27	32	37	42	48	53
	52	5	10	16	21	26	31	36	42	47	52
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
850	929419	9470	9521	9572	9623	9674	9725	9776	9827	9879	51
851	9930	9981	*0032	*0083	*0134	*0185	*0236	*0287	*0338	*0389	51
852	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	51
853	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	51
854	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	51
855	931966	2017	2068	2118	2169	2220	2271	2322	2372	2423	51
856	2474	2524	2575	2626	2677	2727	2778	2829	2879	2930	51
857	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	51
858	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	51
859	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	51
860	934498	4549	4599	4650	4700	4751	4801	4852	4902	4953	50
861	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	50
862	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	50
863	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	50
864	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	50
865	937016	7066	7117	7167	7217	7267	7317	7367	7418	7468	50
866	7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	50
867	8019	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
868	8520	8570	8620	8670	8720	8770	8820	8870	8920	8970	50
869	9020	9070	9120	9170	9220	9270	9320	9369	9419	9469	50
870	939519	9569	9619	9669	9719	9769	9819	9869	9918	9968	50
871	940018	0068	0118	0168	0218	0267	0317	0367	0417	0467	50
872	0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	50
873	1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	50
874	1511	1561	1611	1660	1710	1760	1809	1859	1909	1958	50
875	942008	2058	2107	2157	2207	2256	2306	2355	2405	2455	50
876	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	50
877	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	49
878	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	49
879	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	49
880	944483	4532	4581	4631	4680	4729	4779	4828	4877	4927	49
881	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	49
882	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	49
883	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	49
884	6452	6501	6551	6600	6649	6698	6747	6796	6845	6894	49
885	946943	6992	7041	7090	7140	7189	7238	7287	7336	7385	49
886	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	49
887	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	49
888	8413	8462	8511	8560	8609	8657	8706	8755	8804	8853	49
889	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	49
890	949390	9439	9488	9536	9585	9634	9683	9731	9780	9829	49
891	9878	9926	9975	*0024	*0073	*0121	*0170	*0219	*0267	*0316	49
892	950365	0414	0462	0511	0560	0608	0657	0706	0754	0803	49
893	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	49
894	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	49
895	951823	1872	1920	1969	2017	2066	2114	2163	2211	2260	48
896	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	48
897	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	48
898	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	48
899	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	48

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PR. PTS.	51	5	10	15	20	26	31	36	41	46	51
	50	5	10	15	20	25	30	35	40	45	50
	49	5	10	15	20	25	29	34	39	44	49
	48	5	10	14	19	24	29	34	38	43	48
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
900	954243	4291	4339	4387	4435	4484	4532	4580	4628	4677	48
901	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	48
902	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	48
903	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	48
904	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	48
905	956649	6697	6745	6793	6840	6888	6936	6984	7032	7080	48
906	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	48
907	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	48
908	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	48
909	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	48
910	959041	9089	9137	9185	9232	9280	9328	9375	9423	9471	48
911	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	48
912	9995	*0042	*0090	*0138	*0185	*0233	*0280	*0328	*0376	*0423	48
913	960471	0518	0566	0613	0661	0709	0756	0804	0851	0899	48
914	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	48
915	961421	1469	1516	1563	1611	1658	1706	1753	1801	1848	47
916	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	47
917	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	47
918	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	47
919	3316	3363	3410	3457	3504	3552	3599	3646	3693	3741	47
920	963788	3835	3882	3929	3977	4024	4071	4118	4165	4212	47
921	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	47
922	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	47
923	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	47
924	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
925	966142	6189	6236	6283	6329	6376	6423	6470	6517	6564	47
926	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	47
927	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	47
928	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	47
929	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	47
930	968483	8530	8576	8623	8670	8716	8763	8810	8856	8903	47
931	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	47
932	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	47
933	9882	9928	9975	*0021	*0068	*0114	*0161	*0207	*0254	*0300	47
934	970347	0393	0440	0486	0533	0579	0626	0672	0719	0765	46
935	970812	0858	0904	0951	0997	1044	1090	1137	1183	1229	46
936	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	46
937	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	46
938	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	46
939	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	46
940	973128	3174	3220	3266	3313	3359	3405	3451	3497	3543	46
941	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	46
942	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	46
943	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	46
944	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46
945	975432	5478	5524	5570	5616	5662	5707	5753	5799	5845	46
946	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	46
947	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	46
948	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	46
949	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	46

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PR. PTS.	49	5	10	15	20	25	29	34	39	44	49
	48	5	10	14	19	24	29	34	38	43	48
	47	5	9	14	19	24	28	33	38	42	47
	46	5	9	14	18	23	28	32	37	41	46
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
950	977724	7769	7815	7861	7906	7952	7998	8043	8089	8135	46
951	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	46
952	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	46
953	9093	9138	9184	9230	275	9321	9366	9412	9457	9503	46
954	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	46
955	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	45
956	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	45
957	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	45
958	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	45
959	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	45
960	982271	2316	2362	2407	2452	2497	2543	2588	2633	2678	45
961	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	45
962	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	45
963	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	45
964	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	45
965	984527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
966	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	45
967	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	45
968	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	45
969	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	45
970	986772	6817	6861	6906	6951	6996	7040	7085	7130	7175	45
971	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	45
972	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	45
973	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	45
974	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	45
975	989005	9049	9094	9138	9183	9227	9272	9316	9361	9405	45
976	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	44
977	9895	9939	9983	*0028	*0072	*0117	*0161	*0206	*0250	*0294	44
978	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	44
979	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	44
980	991226	1270	1315	1359	1403	1448	1492	1536	1580	1625	44
981	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	44
982	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	44
983	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	44
984	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	44
985	993436	3480	3524	3568	3613	3657	3701	3745	3789	3833	44
986	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	44
987	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
988	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
989	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	44
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	44
991	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
992	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	44
993	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	44
994	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	44
995	997823	7867	7910	7954	7998	8041	8085	8129	8172	8216	44
996	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	44
997	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	44
998	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	44
999	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PR. PTS.	46	5	9	14	18	23	28	32	37	41	46
	45	5	9	14	18	23	27	32	36	41	45
	44	4	9	13	18	22	26	31	35	40	44
	43	4	9	13	17	22	26	30	34	39	43
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
1000	000000	0043	0087	0130	0174	0217	0260	0304	0347	0391	43
1001	0434	0477	0521	0564	0608	0651	0694	0738	0781	0824	43
1002	0868	0911	0954	0998	1041	1084	1128	1171	1214	1258	43
1003	1301	1344	1388	1431	1474	1517	1561	1604	1647	1690	43
1004	1734	1777	1820	1863	1907	1950	1993	2036	2080	2123	43
1005	002166	2209	2252	2296	2339	2382	2425	2468	2512	2555	43
1006	2598	2641	2684	2727	2771	2814	2857	2900	2943	2986	43
1007	3029	3073	3116	3159	3202	3245	3288	3331	3374	3417	43
1008	3461	3504	3547	3590	3633	3676	3719	3762	3805	3848	43
1009	3891	3934	3977	4020	4063	4106	4149	4192	4235	4278	43
1010	004321	4364	4407	4450	4493	4536	4579	4622	4665	4708	43
1011	4751	4794	4837	4880	4923	4966	5009	5052	5095	5138	43
1012	5181	5223	5266	5309	5352	5395	5438	5481	5524	5567	43
1013	5609	5652	5695	5738	5781	5824	5867	5909	5952	5995	43
1014	6038	6081	6124	6166	6209	6252	6295	6338	6380	6423	43
1015	006466	6509	6552	6594	6637	6680	6723	6765	6808	6851	43
1016	6894	6936	6979	7022	7065	7107	7150	7193	7236	7278	43
1017	7321	7364	7406	7449	7492	7534	7577	7620	7662	7705	43
1018	7748	7790	7833	7876	7918	7961	8004	8046	8089	8132	43
1019	8174	8217	8259	8302	8345	8387	8430	8472	8515	8558	43
1020	008600	8643	8685	8728	8770	8813	8856	8898	8941	8983	43
1021	9026	9068	9111	9153	9196	9238	9281	9323	9366	9408	42
1022	9451	9493	9536	9578	9621	9663	9706	9748	9791	9833	42
1023	9876	9918	9961	*0003	*0045	*0088	*0130	*0173	*0215	*0258	42
1024	010300	0342	0385	0427	0470	0512	0554	0597	0639	0681	42
1025	010724	0766	0809	0851	0893	0936	0978	1020	1063	1105	42
1026	1147	1190	1232	1274	1317	1359	1401	1444	1486	1528	42
1027	1570	1613	1655	1697	1740	1782	1824	1866	1909	1951	42
1028	1993	2035	2078	2120	2162	2204	2247	2289	2331	2373	42
1029	2415	2458	2500	2542	2584	2626	2669	2711	2753	2795	42
1030	012837	2879	2922	2964	3006	3048	3090	3132	3174	3217	42
1031	3259	3301	3343	3385	3427	3469	3511	3553	3596	3638	42
1032	3680	3722	3764	3806	3848	3890	3932	3974	4016	4058	42
1033	4100	4142	4184	4226	4268	4310	4353	4395	4437	4479	42
1034	4521	4563	4605	4647	4689	4730	4772	4814	4856	4898	42
1035	014940	4982	5024	5066	5108	5150	5192	5234	5276	5318	42
1036	5360	5402	5444	5485	5527	5569	5611	5653	5695	5737	42
1037	5779	5821	5863	5904	5946	5988	6030	6072	6114	6156	42
1038	6197	6239	6281	6323	6365	6407	6448	6490	6532	6574	42
1039	6616	6657	6699	6741	6783	6824	6866	6908	6950	6992	42
1040	017033	7075	7117	7159	7200	7242	7284	7326	7367	7409	42
1041	7451	7492	7534	7576	7618	7659	7701	7743	7784	7826	42
1042	7868	7909	7951	7993	8034	8076	8118	8159	8201	8243	42
1043	8284	8326	8368	8409	8451	8492	8534	8576	8617	8659	42
1044	8700	8742	8784	8825	8867	8908	8950	8992	9033	9075	42
1045	019116	9158	9199	9241	9282	9324	9366	9407	9449	9490	42
1046	9532	9573	9615	9656	9698	9739	9781	9822	9864	9905	41
1047	9947	9988	*0030	*0071	*0113	*0154	*0195	*0237	*0278	*0320	41
1048	020361	0403	0444	0486	0527	0568	0610	0651	0693	0734	41
1049	0775	0817	0858	0900	0941	0982	1024	1065	1107	1148	41
1050	021189	1231	1272	1313	1355	1396	1437	1479	1520	1561	41

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
PR. PTS.	44	4	9	13	18	22	26	31	35	40	44
	43	4	9	13	17	22	26	30	34	39	43
	42	4	8	13	17	21	25	29	34	38	42
	41	4	8	12	16	21	25	29	33	37	41
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

TABLE 62

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	—∞		10.000000		—∞		—∞	60
1	6.463726	5017.17	.000000	.00	6.463726	5017.17	3.536274	59
2	.764756	2934.85	.000000	.00	.764756	2934.85	.235244	58
3	.940847	2082.32	.000000	.00	.940847	2082.32	.059153	57
4	7.065786	1615.17	.000000	.00	7.065786	1615.17	2.934214	56
5	7.162696	1319.68	10.000000	.02	7.162696	1319.70	2.837304	55
6	.241877	1115.78	9.999999	.00	.241878	1115.78	.758122	54
7	.308824	966.53	.999999	.00	.308825	966.53	.691175	53
8	.366816	852.53	.999999	.00	.366817	852.55	.633183	52
9	.417968	762.63	.999999	.02	.417970	762.62	.582030	51
10	7.463726	689.87	9.999998	.00	7.463727	689.88	2.536273	50
11	.505118	629.80	.999998	.02	.505120	629.82	.494880	49
12	.542906	579.37	.999997	.00	.542909	579.38	.457091	48
13	.577668	536.42	.999997	.02	.577672	536.42	.422328	47
14	.609853	499.38	.999996	.00	.609857	499.38	.390143	46
15	7.639816	467.15	9.999996	.02	7.639820	467.15	2.360180	45
16	.667845	438.80	.999995	.00	.667849	438.83	.332151	44
17	.694173	413.73	.999995	.02	.694179	413.73	.305821	43
18	.718997	391.35	.999994	.02	.719003	391.35	.280997	42
19	.742478	371.27	.999993	.00	.742484	371.28	.257516	41
20	7.764754	353.15	9.999993	.02	7.764761	353.17	2.235239	40
21	.785943	336.72	.999992	.02	.785951	336.73	.214049	39
22	.806146	321.75	.999991	.02	.806155	321.75	.193845	38
23	.825451	308.05	.999990	.02	.825460	308.07	.174540	37
24	.843934	295.47	.999989	.00	.843944	295.50	.156056	36
25	7.861662	283.88	9.999989	.02	7.861674	283.90	2.138326	35
26	.878695	273.17	.999988	.02	.878708	273.18	.121292	34
27	.895085	263.23	.999987	.02	.895099	263.25	.104901	33
28	.910879	254.00	.999986	.02	.910894	254.00	.089106	32
29	.926119	245.38	.999985	.03	.926134	245.40	.073866	31
30	7.940842	237.33	9.999983	.02	7.940858	237.37	2.059142	30
31	.955082	229.80	.999982	.02	.955100	229.82	.044900	29
32	.968870	222.72	.999981	.02	.968889	222.73	.031111	28
33	.982233	216.08	.999980	.02	.982253	216.10	.017747	27
34	.995198	209.82	.999979	.03	.995219	209.83	.004781	26
35	8.007787	203.90	9.999977	.02	8.007809	203.92	1.992191	25
36	.020021	198.30	.999976	.02	.020044	198.35	.979956	24
37	.031919	193.03	.999975	.03	.031945	193.03	.968055	23
38	.043501	188.00	.999973	.02	.043527	188.03	.956473	22
39	.054781	183.25	.999972	.02	.054809	183.28	.945191	21
40	8.065776	178.73	9.999971	.03	8.065806	178.75	1.934194	20
41	.076500	174.42	.999969	.02	.076531	174.43	.923469	19
42	.086965	170.30	.999968	.03	.086997	170.33	.913003	18
43	.097183	166.40	.999966	.03	.097217	166.43	.902783	17
44	.107167	162.65	.999964	.02	.107203	162.67	.892797	16
45	8.116926	159.08	9.999963	.03	8.116963	159.12	1.883037	15
46	.126471	155.65	.999961	.03	.126510	155.68	.873490	14
47	.135810	152.38	.999959	.02	.135851	152.42	.864149	13
48	.144953	149.23	.999958	.03	.144996	149.27	.855004	12
49	.153907	146.23	.999956	.03	.153952	146.25	.846048	11
50	8.162681	143.32	9.999954	.03	8.162727	143.35	1.837273	10
51	.171280	140.55	.999952	.03	.171328	140.58	.828672	9
52	.179713	137.87	.999950	.03	.179763	137.88	.820237	8
53	.187985	135.28	.999948	.03	.188036	135.33	.811964	7
54	.196102	132.80	.999946	.03	.196156	132.83	.803844	6
55	8.204070	130.42	9.999944	.03	8.204126	130.45	1.795874	5
56	.211895	128.10	.999942	.03	.211953	128.13	.788047	4
57	.219581	125.88	.999940	.03	219641	125.90	.780359	3
58	.227134	123.72	.999938	.03	.227195	123.77	.772805	2
59	.234557	121.63	.999936	.03	.234621	121.67	.765379	1
60	8.241855		9.999934		8.241921		1.758079	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.241855	119.63	9.999934	.03	8.241921	119.68	1.758079	60
1	.249033	117.68	.999932	.05	.249102	117.72	.750898	59
2	.256094	115.80	.999929	.03	.256165	115.83	.743835	58
3	.263042	113.98	.999927	.03	.263115	114.02	.736885	57
4	.269881	112.22	.999925	.05	.269956	112.25	.730044	56
5	8.276614	110.48	9.999922	.03	8.276691	110.53	1.723309	55
6	.283243	108.83	.999920	.03	.283323	108.88	.716677	54
7	.289773	107.23	.999918	.05	.289856	107.27	.710144	53
8	.296207	105.65	.999915	.03	.296292	105.70	.703708	52
9	.302546	104.13	.999913	.05	.302634	104.17	.697366	51
10	8.308794	102.67	9.999910	.05	8.308884	102.70	1.691116	50
11	.314954	101.22	.999907	.03	.315046	101.27	.684954	49
12	.321027	99.82	.999905	.05	.321122	99.87	.678878	48
13	.327016	98.47	.999902	.05	.327114	98.52	.672886	47
14	.332924	97.15	.999899	.03	.333025	97.18	.666975	46
15	8.338753	95.85	9.999897	.05	8.338856	95.90	1.661144	45
16	.344504	94.62	.999894	.05	.344610	94.65	.655390	44
17	.350181	93.37	.999891	.05	.350289	93.43	.649711	43
18	.355783	92.20	.999888	.05	.355895	92.25	.644105	42
19	.361315	91.03	.999885	.05	.361430	91.08	.638570	41
20	8.366777	89.90	9.999882	.05	8.366895	89.95	1.633105	40
21	.372171	88.80	.999879	.05	.372292	88.83	.627708	39
22	.377499	87.72	.999876	.05	.377622	87.78	.622378	38
23	.382762	86.67	.999873	.05	.382889	86.72	.617111	37
24	.387962	85.65	.999870	.05	.388092	85.70	.611908	36
25	8.393101	84.63	9.999867	.05	8.393234	84.68	1.606766	35
26	.398179	83.67	.999864	.05	.398315	83.72	.601685	34
27	.403199	82.70	.999861	.05	.403338	82.77	.596662	33
28	.408161	81.78	.999858	.07	.408304	81.82	.591696	32
29	.413068	80.85	.999854	.05	.413213	80.92	.586787	31
30	8.417919	79.97	9.999851	.05	8.418068	80.02	1.581932	30
31	.422717	79.08	.999848	.07	.422869	79.15	.577131	29
32	.427462	78.23	.999844	.05	.427618	78.28	.572382	28
33	.432156	77.40	.999841	.05	.432315	77.45	.567685	27
34	.436800	76.57	.999838	.07	.436962	76.63	.563038	26
35	8.441394	75.78	9.999834	.05	8.441560	75.83	1.558440	25
36	.445941	74.98	.999831	.07	.446110	75.05	.553890	24
37	.450440	74.22	.999827	.05	.450613	74.28	.549387	23
38	.454893	73.47	.999824	.07	.455070	73.52	.544930	22
39	.459301	72.73	.999820	.07	.459481	72.80	.540519	21
40	8.463665	72.00	9.999816	.05	8.463849	72.05	1.536151	20
41	.467985	71.30	.999813	.07	.468172	71.37	.531828	19
42	.472263	70.58	.999809	.07	.472454	70.65	.527546	18
43	.476498	69.92	.999805	.07	.476693	69.98	.523307	17
44	.480693	69.25	.999801	.07	.480892	69.30	.519108	16
45	8.484848	68.58	9.999797	.05	8.485050	68.67	1.514950	15
46	.488963	67.95	.999794	.07	.489170	68.00	.510830	14
47	.493040	67.30	.999790	.07	.493250	67.38	.506750	13
48	.497078	66.70	.999786	.07	.497293	66.75	.502707	12
49	.501080	66.08	.999782	.07	.501298	66.15	.498702	11
50	8.505045	65.48	9.999778	.07	8.505267	65.55	1.494733	10
51	.508974	64.88	.999774	.08	.509200	64.97	.490800	9
52	.512867	64.32	.999769	.07	.513098	64.38	.486902	8
53	.516726	63.75	.999765	.07	.516961	63.82	.483039	7
54	.520551	63.20	.999761	.07	.520790	63.27	.479210	6
55	8.524343	62.65	9.999757	.07	8.524586	62.72	1.475414	5
56	.528102	62.10	.999753	.08	.528349	62.18	.471651	4
57	.531828	61.58	.999748	.07	.532080	61.65	.467920	3
58	.535523	61.05	.999744	.07	.535779	61.13	.464221	2
59	.539186	60.55	.999740	.08	.539447	60.62	.460553	1
60	8.542819		9.999735		8.543084		1.456916	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.542819	60.05	9.999735	.07	8.543084	60.12	1.456916	60
1	.546422	59.55	.999731	.08	.546691	59.62	.453309	59
2	.549995	59.07	.999726	.07	.550268	59.15	.449732	58
3	.553539	58.58	.999722	.08	.553817	58.65	.446183	57
4	.557054	58.10	.999717	.07	.557336	58.20	.442664	56
5	8.560540	57.65	9.999713	.08	8.560828	57.72	1.439172	55
6	.563999	57.20	.999708	.07	.564291	57.27	.435709	54
7	.567431	56.75	.999704	.08	.567727	56.83	.432273	53
8	.570836	56.30	.999699	.08	.571137	56.38	.428863	52
9	.574214	55.87	.999694	.08	.574520	55.95	.425480	51
10	8.577566	55.43	9.999689	.07	8.577877	55.52	1.422123	50
11	.580892	55.02	.999685	.08	.581208	55.10	.418792	49
12	.584193	54.60	.999680	.08	.584514	54.68	.415486	48
13	.587469	54.20	.999675	.08	.587795	54.27	.412205	47
14	.590721	53.78	.999670	.08	.591051	53.87	.408949	46
15	8.593948	53.40	9.999665	.08	8.594283	53.48	1.405717	45
16	.597152	53.00	.999660	.08	.597492	53.08	.402508	44
17	.600332	52.62	.999655	.08	.600677	52.70	.399323	43
18	.603489	52.23	.999650	.08	.603839	52.32	.396161	42
19	.606623	51.85	.999645	.08	.606978	51.93	.393022	41
20	8.609734	51.48	9.999640	.08	8.610094	51.58	1.389906	40
21	.612823	51.13	.999635	.10	.613189	51.22	.386811	39
22	.615891	50.77	.999629	.08	.616262	50.85	.383738	38
23	.618937	50.42	.999624	.08	.619313	50.50	.380687	37
24	.621962	50.05	.999619	.08	.622343	50.15	.377657	36
25	8.624965	49.72	9.999614	.10	8.625352	49.80	1.374648	35
26	.627948	49.38	.999608	.08	.628340	49.47	.371660	34
27	.630911	49.05	.999603	.10	.631308	49.13	.368692	33
28	.633854	48.70	.999597	.08	.634256	48.80	.365744	32
29	.636776	48.40	.999592	.10	.637184	48.48	.362816	31
30	8.639680	48.05	9.999586	.08	8.640093	48.15	1.359907	30
31	.642563	47.75	.999581	.10	.642982	47.85	.357018	29
32	.645428	47.43	.999575	.08	.645853	47.52	.354147	28
33	.648274	47.13	.999570	.10	.648704	47.22	.351296	27
34	.651102	46.82	.999564	.10	.651537	46.92	.348463	26
35	8.653911	46.52	9.999558	.08	8.654352	46.62	1.345648	25
36	.656702	46.22	.999553	.10	.657149	46.32	.342851	24
37	.659475	45.92	.999547	.10	.659928	46.02	.340072	23
38	.662230	45.63	.999541	.10	.662689	45.73	.337311	22
39	.664968	45.35	.999535	.10	.665433	45.45	.334567	21
40	8.667689	45.07	9.999529	.08	8.668160	45.17	1.331840	20
41	.670393	44.78	.999524	.10	.670870	44.88	.329130	19
42	.673080	44.52	.999518	.10	.673563	44.60	.326437	18
43	.675751	44.23	.999512	.10	.676239	44.35	.323761	17
44	.678405	43.97	.999506	.10	.678900	44.07	.321100	16
45	8.681043	43.70	9.999500	.12	8.681544	43.80	1.318456	15
46	.683665	43.45	.999493	.10	.684172	43.53	.315828	14
47	.686272	43.18	.999487	.10	.686784	43.28	.313216	13
48	.688863	42.92	.999481	.10	.689381	43.03	.310619	12
49	.691438	42.67	.999475	.10	.691963	42.77	.308037	11
50	8.693998	42.42	9.999469	.10	8.694529	42.53	1.305471	10
51	.696543	42.17	.999463	.12	.697081	42.27	.302919	9
52	.699073	41.93	.999456	.10	.699617	42.03	.300383	8
53	.701589	41.68	.999450	.12	.702139	41.78	.297861	7
54	.704090	41.45	.999443	.10	.704646	41.57	.295354	6
55	8.706577	41.20	9.999437	.10	8.707140	41.30	1.292860	5
56	.709049	40.97	.999431	.12	.709618	41.08	.290382	4
57	.711507	40.75	.999424	.10	.712083	40.85	.287917	3
58	.713952	40.52	.999418	.12	.714534	40.63	.285466	2
59	.716383	40.28	.999411	.12	.716972	40.40	.283028	1
60	8.718800		9.999404		8.719396		1.280604	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.718800	40.07	9.999404	.10	8.719396	40.17	1.280604	60
1	.721204	39.85	.999398	.12	.721806	39.97	.278194	59
2	.723595	39.62	.999391	.12	.724204	39.73	.275796	58
3	.725972	39.42	.999384	.10	.726588	39.52	.273412	57
4	.728337	39.18	.999378	.12	.728959	39.30	.271041	56
5	8.730688	38.98	9.999371	.12	8.731317	39.10	1.268683	55
6	.733027	38.78	.999364	.12	.733663	38.88	.266337	54
7	.735354	38.55	.999357	.12	.735996	38.68	.264004	53
8	.737667	38.37	.999350	.12	.738317	38.48	.261683	52
9	.739969	38.17	.999343	.12	.740626	38.27	.259374	51
10	8.742259	37.95	9.999336	.12	8.742922	38.08	1.257078	50
11	.744536	37.77	.999329	.12	.745207	37.87	.254793	49
12	.746802	37.55	.999322	.12	.747479	37.68	.252521	48
13	.749055	37.37	.999315	.12	.749740	37.48	.250260	47
14	.751297	37.18	.999308	.12	.751989	37.30	.248011	46
15	8.753528	36.98	9.999301	.12	8.754227	37.10	1.245773	45
16	.755747	36.80	.999294	.12	.756453	36.92	.243547	44
17	.757955	36.60	.999287	.13	.758668	36.73	.241332	43
18	.760151	36.43	.999279	.12	.760872	36.55	.239128	42
19	.762337	36.23	.999272	.12	.763065	36.35	.236935	41
20	8.764511	36.07	9.999265	.13	8.765246	36.18	1.234754	40
21	.766675	35.88	.999257	.12	.767417	36.02	.232583	39
22	.768828	35.70	.999250	.13	.769578	35.82	.230422	38
23	.770970	35.52	.999242	.12	.771727	35.65	.228273	37
24	.773101	35.37	.999235	.13	.773866	35.48	.226134	36
25	8.775223	35.17	9.999227	.12	8.775995	35.32	1.224005	35
26	.777333	35.02	.999220	.13	.778114	35.13	.221886	34
27	.779434	34.83	.999212	.12	.780222	34.97	.219778	33
28	.781524	34.68	.999205	.13	.782320	34.80	.217680	32
29	.783605	34.50	.999197	.13	.784408	34.63	.215592	31
30	8.785675	34.35	9.999189	.13	8.786486	34.47	1.213514	30
31	.787736	34.18	.999181	.12	.788554	34.32	.211446	29
32	.789787	34.02	.999174	.13	.790613	34.15	.209387	28
33	.791828	33.85	.999166	.13	.792662	33.98	.207338	27
34	.793859	33.70	.999158	.13	.794701	33.83	.205299	26
35	8.795881	33.55	9.999150	.13	8.796731	33.68	1.203269	25
36	.797894	33.38	.999142	.13	.798752	33.52	.201248	24
37	.799897	33.25	.999134	.13	.800763	33.37	.199237	23
38	.801892	33.07	.999126	.13	.802765	33.22	.197235	22
39	.803876	32.93	.999118	.13	.804758	33.07	.195242	21
40	8.805852	32.78	9.999110	.13	8.806742	32.92	1.193258	20
41	.807819	32.63	.999102	.13	.808717	32.77	.191283	19
42	.809777	32.48	.999094	.13	.810683	32.63	.189317	18
43	.811726	32.35	.999086	.15	.812641	32.47	.187359	17
44	.813667	32.20	.999077	.13	.814589	32.33	.185411	16
45	8.815599	32.05	9.999069	.13	8.816529	32.20	1.183471	15
46	.817522	31.90	.999061	.13	.818461	32.05	.181539	14
47	.819436	31.78	.999053	.15	.820384	31.90	.179616	13
48	.821343	31.62	.999044	.13	.822298	31.78	.177702	12
49	.823240	31.50	.999036	.15	.824205	31.63	.175795	11
50	8.825130	31.35	9.999027	.13	8.826103	31.48	1.173897	10
51	.827011	31.22	.999019	.15	.827992	31.37	.172008	9
52	.828884	31.08	.999010	.13	.829874	31.23	.170126	8
53	.830749	30.97	.999002	.15	.831748	31.08	.168252	7
54	.832607	30.82	.998993	.15	.833613	30.97	.166387	6
55	8.834456	30.68	9.998984	.13	8.835471	30.83	1.164529	5
56	.836297	30.55	.998976	.15	.837321	30.70	.162679	4
57	.838130	30.43	.998967	.15	.839163	30.58	.160837	3
58	.839956	30.30	.998958	.13	.840998	30.45	.159002	2
59	.841774	30.18	.998950	.15	.842825	30.32	.157175	1
60	8.843585		9.998941		8.844644		1.155356	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1''.	Cos.	D. 1''.	Tan.	D. 1''.	Cot.	
0	8.843585	30.03	9.998941	.15	8.844644	30.18	1.155356	60
1	.845387	29.93	.998932	.15	.846455	30.08	.153545	59
2	.847183	29.80	.998923	.15	.848260	29.95	.151740	58
3	.848971	29.67	.998914	.15	.850057	29.82	.149943	57
4	.850751	29.57	.998905	.15	.851846	29.70	.148154	56
5	8.852525	29.43	9.998896	.15	8.853628	29.58	1.146372	55
6	.854291	29.30	.998887	.15	.855403	29.47	.144597	54
7	.856049	29.20	.998878	.15	.857171	29.35	.142829	53
8	.857801	29.08	.998869	.15	.858932	29.23	.141068	52
9	.859546	28.95	.998860	.15	.860686	29.12	.139314	51
10	8.861283	28.85	9.998851	.17	8.862433	29.00	1.137567	50
11	.863014	28.73	.998841	.15	.864173	28.88	.135827	49
12	.864738	28.62	.998832	.15	.865906	28.77	.134094	48
13	.866455	28.50	.998823	.17	.867632	28.65	.132368	47
14	.868165	28.38	.998813	.15	.869351	28.55	.130649	46
15	8.869868	28.28	9.998804	.15	8.871064	28.43	1.128936	45
16	.871565	28.17	.998795	.17	.872770	28.32	.127230	44
17	.873255	28.05	.998785	.15	.874469	28.22	.125531	43
18	.874938	27.95	.998776	.17	.876162	28.12	.123838	42
19	.876615	27.83	.998766	.15	.877849	28.00	.122151	41
20	8.878285	27.73	9.998757	.17	8.879529	27.88	1.120471	40
21	.879949	27.63	.998747	.15	.881202	27.78	.118798	39
22	.881607	27.52	.998738	.17	.882869	27.68	.117131	38
23	.883258	27.42	.998728	.17	.884530	27.58	.115470	37
24	.884903	27.32	.998718	.17	.886185	27.47	.113815	36
25	8.886542	27.20	9.998708	.15	8.887833	27.38	1.112167	35
26	.888174	27.12	.998699	.17	.889476	27.27	.110524	34
27	.889801	27.00	.998689	.17	.891112	27.17	.108888	33
28	.891421	26.90	.998679	.17	.892742	27.07	.107258	32
29	.893035	26.80	.998669	.17	.894366	26.97	.105634	31
30	8.894643	26.72	9.998659	.17	8.895984	26.87	1.104016	30
31	.896246	26.60	.998649	.17	.897596	26.78	.102404	29
32	.897842	26.50	.998639	.17	.899203	26.67	.100797	28
33	.899432	26.42	.998629	.17	.900803	26.58	.099197	27
34	.901017	26.32	.998619	.17	.902398	26.48	.097602	26
35	8.902596	26.22	9.998609	.17	8.903987	26.38	1.096013	25
36	.904169	26.12	.998599	.17	.905570	26.28	.094430	24
37	.905736	26.02	.998589	.18	.907147	26.20	.092853	23
38	.907297	25.93	.998578	.17	.908719	26.10	.091281	22
39	.908853	25.85	.998568	.17	.910285	26.02	.089715	21
40	8.910404	25.75	9.998558	.17	8.911846	25.92	1.088154	20
41	.911949	25.65	.998548	.18	.913401	25.83	.086599	19
42	.913488	25.57	.998537	.17	.914951	25.73	.085049	18
43	.915022	25.47	.998527	.18	.916495	25.65	.083505	17
44	.916550	25.38	.998516	.17	.918034	25.57	.081966	16
45	8.918073	25.30	9.998506	.18	8.919568	25.47	1.080432	15
46	.919591	25.20	.998495	.17	.921096	25.38	.078904	14
47	.921103	25.12	.998485	.18	.922619	25.28	.077381	13
48	.922610	25.03	.998474	.17	.924136	25.22	.075864	12
49	.924112	24.95	.998464	.18	.925649	25.12	.074351	11
50	8.925609	24.85	9.998453	.18	8.927156	25.03	1.072844	10
51	.927100	24.78	.998442	.18	.928658	24.95	.071342	9
52	.928587	24.68	.998431	.17	.930155	24.87	.069845	8
53	.930068	24.60	.998421	.18	.931647	24.78	.068353	7
54	.931544	24.52	.998410	.18	.933134	24.70	.066866	6
55	8.933015	24.43	9.998399	.18	8.934616	24.62	1.065384	5
56	.934481	24.35	.998388	.18	.936093	24.53	.063907	4
57	.935942	24.27	.998377	.18	.937565	24.45	.062435	3
58	.937398	24.20	.998366	.18	.939032	24.37	.060968	2
59	.938850	24.10	.998355	.18	.940494	24.30	.059506	1
60	8.940296		9.998344		8.941952		1.058048	0
	Cos.	D. 1''.	Sin.	D. 1''.	Cot.	D. 1''.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.940296	24.03	9.998344	.18	8.941952	24.20	1.058048	60
1	.941738	23.93	.998333	.18	.943404	24.13	.056596	59
2	.943174	23.87	.998322	.18	.944852	24.05	.055148	58
3	.944606	23.80	.998311	.18	.946295	23.98	.053705	57
4	.946034	23.70	.998300	.18	.947734	23.90	.052266	56
5	8.947456	23.63	9.998289	.20	8.949168	23.82	1.050832	55
6	.948874	23.55	.998277	.18	.950597	23.73	.049403	54
7	.950287	23.48	.998266	.18	.952021	23.67	.047979	53
8	.951696	23.40	.998255	.20	.953441	23.58	.046559	52
9	.953100	23.32	.998243	.18	.954856	23.52	.045144	51
10	8.954499	23.25	9.998232	.20	8.956267	23.45	1.043733	50
11	.955894	23.17	.998220	.18	.957674	23.35	.042326	49
12	.957284	23.10	.998209	.20	.959075	23.30	.040925	48
13	.958670	23.03	.998197	.18	.960473	23.22	.039527	47
14	.960052	22.95	.998186	.20	.961866	23.15	.038134	46
15	8.961429	22.87	9.998174	.18	8.963255	23.07	1.036745	45
16	.962801	22.82	.998163	.20	.964639	23.00	.035361	44
17	.964170	22.73	.998151	.20	.966019	22.92	.033981	43
18	.965534	22.65	.998139	.18	.967394	22.87	.032606	42
19	.966893	22.60	.998128	.20	.968766	22.78	.031234	41
20	8.968249	22.52	9.998116	.20	8.970133	22.72	1.029867	40
21	.969600	22.45	.998104	.20	.971496	22.65	.028504	39
22	.970947	22.37	.998092	.20	.972855	22.57	.027145	38
23	.972289	22.32	.998080	.20	.974209	22.52	.025791	37
24	.973628	22.23	.998068	.20	.975560	22.43	.024440	36
25	8.974962	22.18	9.998056	.20	8.976906	22.37	1.023094	35
26	.976293	22.10	.998044	.20	.978248	22.30	.021752	34
27	.977619	22.03	.998032	.20	.979586	22.25	.020414	33
28	.978941	21.97	.998020	.20	.980921	22.17	.019079	32
29	.980259	21.90	.998008	.20	.982251	22.10	.017749	31
30	8.981573	21.83	9.997996	.20	8.983577	22.03	1.016423	30
31	.982883	21.77	.997984	.20	.984899	21.97	.015101	29
32	.984189	21.70	.997972	.22	.986217	21.92	.013783	28
33	.985491	21.63	.997959	.20	.987532	21.83	.012468	27
34	.986789	21.57	.997947	.20	.988842	21.78	.011158	26
35	8.988083	21.52	9.997935	.22	8.990149	21.70	1.009851	25
36	.989374	21.43	.997922	.20	.991451	21.65	.008549	24
37	.990660	21.38	.997910	.22	.992750	21.58	.007250	23
38	.991943	21.32	.997897	.20	.994045	21.53	.005955	22
39	.993222	21.25	.997885	.22	.995337	21.45	.004663	21
40	8.994497	21.18	9.997872	.20	8.996624	21.40	1.003376	20
41	.995768	21.13	.997860	.22	.997908	21.33	.002092	19
42	.997036	21.05	.997847	.20	.999188	21.28	.000812	18
43	.998299	21.02	.997835	.22	9.000465	21.22	0.999535	17
44	.999560	20.93	.997822	.22	.001738	21.15	.998262	16
45	9.000816	20.88	9.997809	.20	9.003007	21.08	0.996993	15
46	.002069	20.82	.997797	.22	.004272	21.03	.995728	14
47	.003318	20.75	.997784	.22	.005534	20.97	.994466	13
48	.004563	20.70	.997771	.22	.006792	20.92	.993208	12
49	.005805	20.65	.997758	.22	.008047	20.85	.991953	11
50	9.007044	20.57	9.997745	.22	9.009298	20.80	0.990702	10
51	.008278	20.53	.997732	.22	.010546	20.73	.989454	9
52	.009510	20.45	.997719	.22	.011790	20.68	.988210	8
53	.010737	20.42	.997706	.22	.013031	20.62	.986969	7
54	.011962	20.33	.997693	.22	.014268	20.57	.985732	6
55	9.013182	20.30	9.997680	.22	9.015502	20.50	0.984498	5
56	.014400	20.22	.997667	.22	.016732	20.45	.983268	4
57	.015613	20.18	.997654	.22	.017959	20.40	.982041	3
58	.016824	20.12	.997641	.22	.019183	20.33	.980817	2
59	.018031	20.07	.997628	.23	.020403	20.28	.979597	1
60	9.019235		9.997614		9.021620		0.978380	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.019235	20.00	9.997614	.22	9.021620	20.23	0.978380	60
1	.020435	19.95	.997601	.22	.022834	20.17	.977166	59
2	.021632	19.88	.997588	.23	.024044	20.12	.975956	58
3	.022825	19.85	.997574	.22	.025251	20.07	.974749	57
4	.024016	19.78	.997561	.23	.026455	20.00	.973545	56
5	9.025203	19.72	9.997547	.22	9.027655	19.95	0.972345	55
6	.026386	19.68	.997534	.23	.028852	19.90	.971148	54
7	.027567	19.62	.997520	.22	.030046	19.85	.969954	53
8	.028744	19.57	.997507	.23	.031237	19.80	.968763	52
9	.029918	19.52	.997493	.22	.032425	19.73	.967575	51
10	9.031089	19.47	9.997480	.23	9.033609	19.70	0.966391	50
11	.032257	19.40	.997466	.23	.034791	19.63	.965209	49
12	.033421	19.35	.997452	.22	.035969	19.58	.964031	48
13	.034582	19.32	.997439	.23	.037144	19.53	.962856	47
14	.035741	19.25	.997425	.23	.038316	19.48	.961684	46
15	9.036896	19.20	9.997411	.23	9.039485	19.43	0.960515	45
16	.038048	19.15	.997397	.23	.040651	19.37	.959349	44
17	.039197	19.08	.997383	.23	.041813	19.33	.958187	43
18	.040342	19.05	.997369	.23	.042973	19.28	.957027	42
19	.041485	19.00	.997355	.23	.044130	19.23	.955870	41
20	9.042625	18.95	9.997341	.23	9.045284	19.17	0.954716	40
21	.043762	18.88	.997327	.23	.046434	19.13	.953566	39
22	.044895	18.85	.997313	.23	.047582	19.08	.952418	38
23	.046026	18.80	.997299	.23	.048727	19.03	.951273	37
24	.047154	18.75	.997285	.23	.049869	18.98	.950131	36
25	9.048279	18.68	9.997271	.23	9.051008	18.93	0.948992	35
26	.049400	18.65	.997257	.25	.052144	18.88	.947856	34
27	.050519	18.60	.997242	.23	.053277	18.83	.946723	33
28	.051635	18.57	.997228	.23	.054407	18.80	.945593	32
29	.052749	18.50	.997214	.25	.055535	18.73	.944465	31
30	9.053859	18.45	9.997199	.23	9.056659	18.70	0.943341	30
31	.054966	18.42	.997185	.25	.057781	18.65	.942219	29
32	.056071	18.35	.997170	.23	.058900	18.60	.941100	28
33	.057172	18.32	.997156	.25	.060016	18.57	.939984	27
34	.058271	18.27	.997141	.23	.061130	18.50	.938870	26
35	9.059367	18.22	9.997127	.25	9.062240	18.47	0.937760	25
36	.060460	18.18	.997112	.23	.063348	18.42	.936652	24
37	.061551	18.13	.997098	.25	.064453	18.38	.935547	23
38	.062639	18.08	.997083	.25	.065556	18.32	.934444	22
39	.063724	18.03	.997068	.25	.066655	18.28	.933345	21
40	9.064806	17.98	9.997053	.23	9.067752	18.23	0.932248	20
41	.065885	17.95	.997039	.25	.068846	18.20	.931154	19
42	.066962	17.90	.997024	.25	.069938	18.15	.930062	18
43	.068036	17.85	.997009	.25	.071027	18.10	.928973	17
44	.069107	17.82	.996994	.25	.072113	18.07	.927887	16
45	9.070176	17.77	9.996979	.25	9.073197	18.02	0.926803	15
46	.071242	17.73	.996964	.25	.074278	17.97	.925722	14
47	.072306	17.67	.996949	.25	.075356	17.93	.924644	13
48	.073366	17.63	.996934	.25	.076432	17.88	.923568	12
49	.074424	17.60	.996919	.25	.077505	17.85	.922495	11
50	9.075480	17.55	9.996904	.25	9.078576	17.80	0.921424	10
51	.076533	17.50	.996889	.25	.079644	17.77	.920356	9
52	.077583	17.47	.996874	.27	.080710	17.72	.919290	8
53	.078631	17.42	.996858	.25	.081773	17.67	.918227	7
54	.079676	17.38	.996843	.25	.082833	17.63	.917167	6
55	9.080719	17.33	9.996828	.27	9.083891	17.60	0.916109	5
56	.081759	17.30	.996812	.25	.084947	17.55	.915053	4
57	.082797	17.25	.996797	.25	.086000	17.50	.914000	3
58	.083832	17.20	.996782	.27	.087050	17.47	.912950	2
59	.084864	17.17	.996766	.25	.088098	17.43	.911902	1
60	9.085894		9.996751		9.089144		0.910856	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.085894	17.13	9.996751	.27	9.089144	17.38	0.910856	60
1	.086922	17.08	.996735	.25	.090187	17.35	.909813	59
2	.087947	17.05	.996720	.27	.091228	17.30	.908772	58
3	.088970	17.00	.996704	.27	.092266	17.27	.907734	57
4	.089990	16.97	.996688	.25	.093302	17.23	.906698	56
5	9.091008	16.93	9.996673	.27	9.094336	17.18	0.905664	55
6	.092024	16.88	.996657	.27	.095367	17.13	.904633	54
7	.093037	16.83	.996641	.27	.096395	17.12	.903605	53
8	.094047	16.82	.996625	.25	.097422	17.07	.902578	52
9	.095056	16.77	.996610	.27	.098446	17.03	.901554	51
10	9.096062	16.72	9.996594	.27	9.099468	16.98	0.900532	50
11	.097065	16.68	.996578	.27	.100487	16.95	.899513	49
12	.098066	16.65	.996562	.27	.101504	16.92	.898496	48
13	.099065	16.62	.996546	.27	.102519	16.88	.897481	47
14	.100062	16.57	.996530	.27	.103532	16.83	.896468	46
15	9.101056	16.53	9.996514	.27	9.104542	16.80	0.895458	45
16	.102048	16.48	.996498	.27	.105550	16.77	.894450	44
17	.103037	16.47	.996482	.28	.106556	16.72	.893444	43
18	.104025	16.42	.996465	.27	.107559	16.68	.892441	42
19	.105010	16.37	.996449	.27	.108560	16.65	.891440	41
20	9.105992	16.35	9.996433	.27	9.109559	16.62	0.890441	40
21	.106973	16.30	.996417	.28	.110556	16.58	.889444	39
22	.107951	16.27	.996400	.27	.111551	16.53	.888449	38
23	.108927	16.23	.996384	.27	.112543	16.50	.887457	37
24	.109901	16.20	.996368	.28	.113533	16.47	.886467	36
25	9.110873	16.15	9.996351	.27	9.114521	16.43	0.885479	35
26	.111842	16.12	.996335	.28	.115507	16.40	.884493	34
27	.112809	16.08	.996318	.27	.116491	16.35	.883509	33
28	.113774	16.05	.996302	.28	.117472	16.33	.882528	32
29	.114737	16.02	.996285	.27	.118452	16.28	.881548	31
30	9.115698	15.97	9.996269	.28	9.119429	16.25	0.880571	30
31	.116656	15.95	.996252	.28	.120404	16.22	.879596	29
32	.117613	15.90	.996235	.27	.121377	16.18	.878623	28
33	.118567	15.87	.996219	.28	.122348	16.15	.877652	27
34	.119519	15.83	.996202	.28	.123317	16.12	.876683	26
35	9.120469	15.80	9.996185	.28	9.124284	16.08	0.875716	25
36	.121417	15.75	.996168	.28	.125249	16.03	.874751	24
37	.122362	15.73	.996151	.28	.126211	16.02	.873789	23
38	.123306	15.70	.996134	.28	.127172	15.97	.872828	22
39	.124248	15.65	.996117	.28	.128130	15.95	.871870	21
40	9.125187	15.63	9.996100	.28	9.129087	15.90	0.870913	20
41	.126125	15.58	.996083	.28	.130041	15.88	.869959	19
42	.127060	15.55	.996066	.28	.130994	15.83	.869006	18
43	.127993	15.53	.996049	.28	.131944	15.82	.868056	17
44	.128925	15.48	.996032	.28	.132893	15.77	.867107	16
45	9.129854	15.45	9.996015	.28	9.133839	15.75	0.866161	15
46	.130781	15.42	.995998	.30	.134784	15.70	.865216	14
47	.131706	15.40	.995980	.28	.135726	15.68	.864274	13
48	.132630	15.35	.995963	.28	.136667	15.63	.863333	12
49	.133551	15.32	.995946	.30	.137605	15.62	.862395	11
50	9.134470	15.28	9.995928	.28	9.138542	15.57	0.861458	10
51	.135387	15.27	.995911	.28	.139476	15.55	.860524	9
52	.136303	15.22	.995894	.30	.140409	15.52	.859591	8
53	.137216	15.20	.995876	.28	.141340	15.48	.858660	7
54	.138128	15.15	.995859	.30	.142269	15.45	.857731	6
55	9.139037	15.12	9.995841	.30	9.143196	15.42	0.856804	5
56	.139944	15.10	.995823	.28	.144121	15.38	.855879	4
57	.140850	15.07	.995806	.30	.145044	15.37	.854956	3
58	.141754	15.02	.995788	.28	.145966	15.32	.854034	2
59	.142655	15.00	.995771	.30	.146885	15.30	.853115	1
60	9.143555		9.995753		9.147803		0.852197	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.143555	14.97	9.995753	.30	9.147803	15.25	0.852197	60
1	.144453	14.93	.995735	.30	.148718	15.23	.851282	59
2	.145349	14.90	.995717	.30	.149632	15.20	.850368	58
3	.146243	14.88	.995699	.30	.150544	15.17	.849456	57
4	.147136	14.83	.995681	.28	.151454	15.15	.848546	56
5	9.148026	14.82	9.995664	.30	9.152363	15.10	0.847637	55
6	.148915	14.78	.995646	.30	.153269	15.08	.846731	54
7	.149802	14.73	.995628	.30	.154174	15.05	.845826	53
8	.150686	14.72	.995610	.32	.155077	15.02	.844923	52
9	.151569	14.70	.995591	.30	.155978	14.98	.844022	51
10	9.152451	14.65	9.995573	.30	9.156877	14.97	0.843123	50
11	.153330	14.63	.995555	.30	.157775	14.93	.842225	49
12	.154208	14.58	.995537	.30	.158671	14.90	.841329	48
13	.155083	14.57	.995519	.30	.159565	14.87	.840435	47
14	.155957	14.55	.995501	.32	.160457	14.83	.839543	46
15	9.156830	14.50	9.995482	.30	9.161347	14.82	0.838653	45
16	.157700	14.48	.995464	.30	.162236	14.78	.837764	44
17	.158569	14.43	.995446	.32	.163123	14.75	.836877	43
18	.159435	14.43	.995427	.30	.164008	14.73	.835992	42
19	.160301	14.38	.995409	.32	.164892	14.70	.835108	41
20	9.161164	14.35	9.995390	.30	9.165774	14.67	0.834226	40
21	.162025	14.33	.995372	.32	.166654	14.63	.833346	39
22	.162885	14.30	.995353	.32	.167532	14.62	.832468	38
23	.163743	14.28	.995334	.30	.168409	14.58	.831591	37
24	.164600	14.23	.995316	.32	.169284	14.55	.830716	36
25	9.165454	14.22	9.995297	.32	9.170157	14.53	0.829843	35
26	.166307	14.20	.995278	.30	.171029	14.50	.828971	34
27	.167159	14.15	.995260	.32	.171899	14.47	.828101	33
28	.168008	14.13	.995241	.32	.172767	14.45	.827233	32
29	.168856	14.10	.995222	.32	.173634	14.42	.826366	31
30	9.169702	14.08	9.995203	.32	9.174499	14.38	0.825501	30
31	.170547	14.03	.995184	.32	.175362	14.37	.824638	29
32	.171389	14.02	.995165	.32	.176224	14.33	.823776	28
33	.172230	14.00	.995146	.32	.177084	14.30	.822916	27
34	.173070	13.97	.995127	.32	.177942	14.28	.822058	26
35	9.173908	13.93	9.995108	.32	9.178799	14.27	0.821201	25
36	.174744	13.90	.995089	.32	.179655	14.22	.820345	24
37	.175578	13.88	.995070	.32	.180508	14.20	.819492	23
38	.176411	13.85	.995051	.32	.181360	14.18	.818640	22
39	.177242	13.83	.995032	.32	.182211	14.13	.817789	21
40	9.178072	13.80	9.995013	.33	9.183059	14.13	0.816941	20
41	.178900	13.77	.994993	.32	.183907	14.08	.816093	19
42	.179726	13.75	.994974	.32	.184752	14.08	.815248	18
43	.180551	13.72	.994955	.33	.185597	14.03	.814403	17
44	.181374	13.70	.994935	.32	.186439	14.02	.813561	16
45	9.182196	13.67	9.994916	.33	9.187280	14.00	0.812720	15
46	.183016	13.63	.994896	.32	.188120	13.97	.811880	14
47	.183834	13.62	.994877	.33	.188958	13.93	.811042	13
48	.184651	13.58	.994857	.32	.189794	13.92	.810206	12
49	.185466	13.57	.994838	.33	.190629	13.88	.809371	11
50	9.186280	13.53	9.994818	.33	9.191462	13.87	0.808538	10
51	.187092	13.52	.994798	.32	.192294	13.83	.807706	9
52	.187903	13.48	.994779	.33	.193124	13.82	.806876	8
53	.188712	13.45	.994759	.33	.193953	13.78	.806047	7
54	.189519	13.43	.994739	.32	.194780	13.77	.805220	6
55	9.190325	13.42	9.994720	.33	9.195606	13.73	0.804394	5
56	.191130	13.38	.994700	.33	.196430	13.72	.803570	4
57	.191933	13.35	.994680	.33	.197253	13.68	.802747	3
58	.192734	13.33	.994660	.33	.198074	13.67	.801926	2
59	.193534	13.30	.994640	.33	.198894	13.65	.801106	1
60	9.194332		9.994620		9.199713		0.800287	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.194332	13.28	9.994620	.33	9.199713	13.60	0.800287	60
1	.195129	13.27	.994600	.33	.200529	13.60	.799471	59
2	.195925	13.23	.994580	.33	.201345	13.57	.798655	58
3	.196719	13.20	.994560	.33	.202159	13.53	.797841	57
4	.197511	13.18	.994540	.35	.202971	13.52	.797029	56
5	9.198302	13.15	9.994519	.33	9.203782	13.50	0.796218	55
6	.199091	13.13	.994499	.33	.204592	13.47	.795408	54
7	.199879	13.12	.994479	.33	.205400	13.45	.794600	53
8	.200666	13.08	.994459	.35	.206207	13.43	.793793	52
9	.201451	13.05	.994438	.33	.207013	13.40	.792987	51
10	9.202234	13.05	9.994418	.33	9.207817	13.37	0.792183	50
11	.203017	13.00	.994398	.35	.208619	13.35	.791381	49
12	.203797	13.00	.994377	.33	.209420	13.33	.790580	48
13	.204577	12.95	.994357	.35	.210220	13.30	.789780	47
14	.205354	12.95	.994336	.33	.211018	13.28	.788982	46
15	9.206131	12.92	9.994316	.35	9.211815	13.27	0.788185	45
16	.206906	12.88	.994295	.35	.212611	13.23	.787389	44
17	.207679	12.88	.994274	.33	.213405	13.22	.786595	43
18	.208452	12.83	.994254	.35	.214198	13.18	.785802	42
19	.209222	12.83	.994233	.35	.214989	13.18	.785011	41
20	9.209992	12.80	9.994212	.35	9.215780	13.13	0.784220	40
21	.210760	12.77	.994191	.33	.216568	13.13	.783432	39
22	.211526	12.75	.994171	.35	.217356	13.10	.782644	38
23	.212291	12.73	.994150	.35	.218142	13.07	.781858	37
24	.213055	12.72	.994129	.35	.218926	13.07	.781074	36
25	9.213818	12.68	9.994108	.35	9.219710	13.03	0.780290	35
26	.214579	12.65	.994087	.35	.220492	13.00	.779508	34
27	.215338	12.65	.994066	.35	.221272	13.00	.778728	33
28	.216097	12.62	.994045	.35	.222052	12.97	.777948	32
29	.216854	12.58	.994024	.35	.222830	12.95	.777170	31
30	9.217609	12.57	9.994003	.35	9.223607	12.92	0.776393	30
31	.218363	12.55	.993982	.37	.224382	12.90	.775618	29
32	.219116	12.53	.993960	.35	.225156	12.88	.774844	28
33	.219868	12.50	.993939	.35	.225929	12.85	.774071	27
34	.220618	12.48	.993918	.35	.226700	12.85	.773300	26
35	9.221367	12.47	9.993897	.37	9.227471	12.80	0.772529	25
36	.222115	12.43	.993875	.35	.228239	12.80	.771761	24
37	.222861	12.42	.993854	.37	.229007	12.77	.770993	23
38	.223606	12.38	.993832	.35	.229773	12.77	.770227	22
39	.224349	12.38	.993811	.37	.230539	12.72	.769461	21
40	9.225092	12.35	9.993789	.35	9.231302	12.72	0.768698	20
41	.225833	12.33	.993768	.37	.232065	12.68	.767935	19
42	.226573	12.30	.993746	.35	.232826	12.67	.767174	18
43	.227311	12.28	.993725	.37	.233586	12.65	.766414	17
44	.228048	12.27	.993703	.37	.234345	12.63	.765655	16
45	9.228784	12.23	9.993681	.35	9.235103	12.60	0.764897	15
46	.229518	12.23	.993660	.37	.235859	12.58	.764141	14
47	.230252	12.20	.993638	.37	.236614	12.57	.763386	13
48	.230984	12.18	.993616	.37	.237368	12.53	.762632	12
49	.231715	12.15	.993594	.37	.238120	12.53	.761880	11
50	9.232444	12.13	9.993572	.37	9.238872	12.50	0.761128	10
51	.233172	12.12	.993550	.37	.239622	12.48	.760378	9
52	.233899	12.10	.993528	.37	.240371	12.45	.759629	8
53	.234625	12.07	.993506	.37	.241118	12.45	.758882	7
54	.235349	12.07	.993484	.37	.241865	12.42	.758135	6
55	9.236073	12.03	9.993462	.37	9.242610	12.40	0.757390	5
56	.236795	12.00	.993440	.37	.243354	12.38	.756646	4
57	.237515	12.00	.993418	.37	.244097	12.37	.755903	3
58	.238235	11.97	.993396	.37	.244839	12.33	.755161	2
59	.238953	11.95	.993374	.38	.245579	12.33	.754421	1
60	9.239670		9.993351		9.246319		0.753681	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.239670	11.93	9.993351	.37	9.246319	12.30	0.753681	60
1	.240386	11.92	.993329	.37	.247057	12.28	.752943	59
2	.241101	11.88	.993307	.38	.247794	12.27	.752206	58
3	.241814	11.87	.993284	.37	.248530	12.23	.751470	57
4	.242526	11.85	.993262	.37	.249264	12.23	.750736	56
5	9.243237	11.83	9.993240	.38	9.249998	12.20	0.750002	55
6	.243947	11.82	.993217	.37	.250730	12.18	.749270	54
7	.244656	11.78	.993195	.38	.251461	12.17	.748539	53
8	.245363	11.77	.993172	.38	.252191	12.15	.747809	52
9	.246069	11.77	.993149	.37	.252920	12.13	.747080	51
10	9.246775	11.72	9.993127	.38	9.253648	12.10	0.746352	50
11	.247478	11.72	.993104	.38	.254374	12.10	.745626	49
12	.248181	11.70	.993081	.37	.255100	12.07	.744900	48
13	.248883	11.67	.993059	.38	.255824	12.05	.744176	47
14	.249583	11.65	.993036	.38	.256547	12.03	.743453	46
15	9.250282	11.63	9.993013	.38	9.257269	12.02	0.742731	45
16	.250980	11.62	.992990	.38	.257990	12.00	.742010	44
17	.251677	11.60	.992967	.38	.258710	11.98	.741290	43
18	.252373	11.57	.992944	.38	.259429	11.95	.740571	42
19	.253067	11.57	.992921	.38	.260146	11.95	.739854	41
20	9.253761	11.53	9.992898	.38	9.260863	11.92	0.739137	40
21	.254453	11.52	.992875	.38	.261578	11.90	.738422	39
22	.255144	11.50	.992852	.38	.262292	11.88	.737708	38
23	.255834	11.48	.992829	.38	.263005	11.87	.736995	37
24	.256523	11.47	.992806	.38	.263717	11.85	.736283	36
25	9.257211	11.45	9.992783	.40	9.264428	11.83	0.735572	35
26	.257898	11.42	.992759	.38	.265138	11.82	.734862	34
27	.258583	11.42	.992736	.38	.265847	11.80	.734153	33
28	.259268	11.38	.992713	.38	.266555	11.77	.733445	32
29	.259951	11.37	.992690	.40	.267261	11.77	.732739	31
30	9.260633	11.35	9.992666	.38	9.267967	11.73	0.732033	30
31	.261314	11.33	.992643	.40	.268671	11.73	.731329	29
32	.261994	11.32	.992619	.38	.269375	11.70	.730625	28
33	.262673	11.30	.992596	.40	.270077	11.70	.729923	27
34	.263351	11.27	.992572	.38	.270779	11.67	.729221	26
35	9.264027	11.27	9.992549	.40	9.271479	11.65	0.728521	25
36	.264703	11.23	.992525	.40	.272178	11.63	.727822	24
37	.265377	11.23	.992501	.38	.272876	11.62	.727124	23
38	.266051	11.20	.992478	.40	.273573	11.60	.726427	22
39	.266723	11.20	.992454	.40	.274269	11.58	.725731	21
40	9.267395	11.17	9.992430	.40	9.274964	11.57	0.725036	20
41	.268065	11.15	.992406	.40	.275658	11.55	.724342	19
42	.268734	11.13	.992382	.38	.276351	11.53	.723649	18
43	.269402	11.12	.992359	.40	.277043	11.52	.722957	17
44	.270069	11.10	.992335	.40	.277734	11.50	.722266	16
45	9.270735	11.08	9.992311	.40	9.278424	11.48	0.721576	15
46	.271400	11.07	.992287	.40	.279113	11.47	.720887	14
47	.272064	11.03	.992263	.40	.279801	11.45	.720199	13
48	.272726	11.03	.992239	.42	.280488	11.43	.719512	12
49	.273388	11.02	.992214	.40	.281174	11.40	.718826	11
50	9.274049	10.98	9.992190	.40	9.281858	11.40	0.718142	10
51	.274708	10.98	.992166	.40	.282542	11.38	.717458	9
52	.275367	10.97	.992142	.40	.283225	11.37	.716775	8
53	.276025	10.93	.992118	.42	.283907	11.35	.716093	7
54	.276681	10.93	.992093	.40	.284588	11.33	.715412	6
55	9.277337	10.90	9.992069	.42	9.285268	11.32	0.714732	5
56	.277991	10.90	.992044	.40	.285947	11.28	.714053	4
57	.278645	10.87	.992020	.40	.286624	11.28	.713376	3
58	.279297	10.85	.991996	.42	.287301	11.27	.712699	2
59	.279948	10.85	.991971	.40	.287977	11.25	.712023	1
60	9.280599		9.991947		9.288652		0.711348	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.280599	10.82	9.991947	.42	9.288652	11.23	0.711348	60
1	.281248	10.82	.991922	.42	.289326	11.22	.710674	59
2	.281897	10.78	.991897	.40	.289999	11.20	.710001	58
3	.282544	10.77	.991873	.42	.290671	11.18	.709329	57
4	.283190	10.77	.991848	.42	.291342	11.18	.708658	56
5	9.283836	10.73	9.991823	.40	9.292013	11.15	0.707987	55
6	.284480	10.73	.991799	.42	.292682	11.13	.707318	54
7	.285124	10.70	.991774	.42	.293350	11.12	.706650	53
8	.285766	10.70	.991749	.42	.294017	11.12	.705983	52
9	.286408	10.67	.991724	.42	.294684	11.08	.705316	51
10	9.287048	10.67	9.991699	.42	9.295349	11.07	0.704651	50
11	.287688	10.63	.991674	.42	.296013	11.07	.703987	49
12	.288326	10.63	.991649	.42	.296677	11.03	.703323	48
13	.288964	10.60	.991624	.42	.297339	11.03	.702661	47
14	.289600	10.60	.991599	.42	.298001	11.02	.701999	46
15	9.290236	10.57	9.991574	.42	9.298662	11.00	0.701338	45
16	.290870	10.57	.991549	.42	.299322	10.97	.700678	44
17	.291504	10.55	.991524	.43	.299980	10.97	.700020	43
18	.292137	10.52	.991498	.42	.300638	10.95	.699362	42
19	.292768	10.52	.991473	.42	.301295	10.93	.698705	41
20	9.293399	10.50	9.991448	.43	9.301951	10.93	0.698049	40
21	.294029	10.48	.991422	.42	.302607	10.90	.697393	39
22	.294658	10.47	.991397	.42	.303261	10.88	.696739	38
23	.295286	10.45	.991372	.43	.303914	10.88	.696086	37
24	.295913	10.43	.991346	.42	.304567	10.85	.695433	36
25	9.296539	10.42	9.991321	.43	9.305218	10.85	0.694782	35
26	.297164	10.40	.991295	.42	.305869	10.83	.694131	34
27	.297788	10.40	.991270	.43	.306519	10.82	.693481	33
28	.298412	10.37	.991244	.43	.307168	10.80	.692832	32
29	.299034	10.35	.991218	.42	.307816	10.78	.692184	31
30	9.299655	10.35	9.991193	.43	9.308463	10.77	0.691537	30
31	.300276	10.32	.991167	.43	.309109	10.75	.690891	29
32	.300895	10.32	.991141	.43	.309754	10.75	.690246	28
33	.301514	10.30	.991115	.42	.310399	10.72	.689601	27
34	.302132	10.27	.991090	.43	.311042	10.72	.688958	26
35	9.302748	10.27	9.991064	.43	9.311685	10.70	0.688315	25
36	.303364	10.25	.991038	.43	.312327	10.68	.687673	24
37	.303979	10.23	.991012	.43	.312968	10.67	.687032	23
38	.304593	10.23	.990986	.43	.313608	10.65	.686392	22
39	.305207	10.20	.990960	.43	.314247	10.63	.685753	21
40	9.305819	10.18	9.990934	.43	9.314885	10.63	0.685115	20
41	.306430	10.18	.990908	.43	.315523	10.60	.684477	19
42	.307041	10.15	.990882	.45	.316159	10.60	.683841	18
43	.307650	10.15	.990855	.43	.316795	10.58	.683205	17
44	.308259	10.13	.990829	.43	.317430	10.57	.682570	16
45	9.308867	10.12	9.990803	.43	9.318064	10.55	0.681936	15
46	.309474	10.10	.990777	.45	.318697	10.55	.681303	14
47	.310080	10.08	.990750	.43	.319330	10.52	.680670	13
48	.310685	10.07	.990724	.45	.319961	10.52	.680039	12
49	.311289	10.07	.990697	.43	.320592	10.50	.679408	11
50	9.311893	10.03	9.990671	.43	9.321222	10.48	0.678778	10
51	.312495	10.03	.990645	.45	.321851	10.47	.678149	9
52	.313097	10.02	.990618	.45	.322479	10.45	.677521	8
53	.313698	9.98	.990591	.43	.323106	10.45	.676894	7
54	.314297	10.00	.990565	.45	.323733	10.42	.676267	6
55	9.314897	9.97	9.990538	.45	9.324358	10.42	0.675642	5
56	.315495	9.95	.990511	.43	.324983	10.40	.675017	4
57	.316092	9.95	.990485	.45	.325607	10.40	.674393	3
58	.316689	9.92	.990458	.45	.326231	10.37	.673769	2
59	.317284	9.92	.990431	.45	.326853	10.37	.673147	1
60	9.317879		9.990404		9.327475		0.672525	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.317879	9.90	9.990404	.43	9.327475	10.33	0.672525	60
1	.318473	9.88	.990378	.45	.328095	10.33	.671905	59
2	.319066	9.87	.990351	.45	.328715	10.32	.671285	58
3	.319658	9.85	.990324	.45	.329334	10.32	.670666	57
4	.320249	9.85	.990297	.45	.329953	10.28	.670047	56
5	9.320840	9.83	9.990270	.45	9.330570	10.28	0.669430	55
6	.321430	9.82	.990243	.47	.331187	10.27	.668813	54
7	.322019	9.80	.990215	.45	.331803	10.25	.668197	53
8	.322607	9.78	.990188	.45	.332418	10.25	.667582	52
9	.323194	9.77	.990161	.45	.333033	10.22	.666967	51
10	9.323780	9.77	9.990134	.45	9.333646	10.22	0.666354	50
11	.324366	9.73	.990107	.47	.334259	10.20	.665741	49
12	.324950	9.73	.990079	.45	.334871	10.18	.665129	48
13	.325534	9.72	.990052	.45	.335482	10.18	.664518	47
14	.326117	9.72	.990025	.47	.336093	10.15	.663907	46
15	9.326700	9.68	9.989997	.45	9.336702	10.15	0.663298	45
16	.327281	9.68	.989970	.47	.337311	10.13	.662689	44
17	.327862	9.67	.989942	.45	.337919	10.13	.662081	43
18	.328442	9.65	.989915	.47	.338527	10.10	.661473	42
19	.329021	9.63	.989887	.45	.339133	10.10	.660867	41
20	9.329599	9.62	9.989860	.47	9.339739	10.08	0.660261	40
21	.330176	9.62	.989832	.47	.340344	10.07	.659656	39
22	.330753	9.60	.989804	.45	.340948	10.07	.659052	38
23	.331329	9.57	.989777	.47	.341552	10.05	.658448	37
24	.331903	9.58	.989749	.47	.342155	10.03	.657845	36
25	9.332478	9.55	9.989721	.47	9.342757	10.02	0.657243	35
26	.333051	9.55	.989693	.47	.343358	10.00	.656642	34
27	.333624	9.52	.989665	.47	.343958	10.00	.656042	33
28	.334195	9.53	.989637	.45	.344558	9.98	.655442	32
29	.334767	9.50	.989610	.47	.345157	9.97	.654843	31
30	9.335337	9.48	9.989582	.48	9.345755	9.97	0.654245	30
31	.335906	9.48	.989553	.47	.346353	9.93	.653647	29
32	.336475	9.47	.989525	.47	.346949	9.93	.653051	28
33	.337043	9.45	.989497	.47	.347545	9.93	.652455	27
34	.337610	9.43	.989469	.47	.348141	9.90	.651859	26
35	9.338176	9.43	9.989441	.47	9.348735	9.90	0.651265	25
36	.338742	9.42	.989413	.47	.349329	9.88	.650671	24
37	.339307	9.40	.989385	.48	.349922	9.87	.650078	23
38	.339871	9.38	.989356	.47	.350514	9.87	.649486	22
39	.340434	9.37	.989328	.47	.351106	9.85	.648894	21
40	9.340996	9.37	9.989300	.48	9.351697	9.83	0.648303	20
41	.341558	9.35	.989271	.47	.352287	9.82	.647713	19
42	.342119	9.33	.989243	.48	.352876	9.82	.647124	18
43	.342679	9.33	.989214	.47	.353465	9.80	.646535	17
44	.343239	9.30	.989186	.48	.354053	9.78	.645947	16
45	9.343797	9.30	9.989157	.48	9.354640	9.78	0.645360	15
46	.344355	9.28	.989128	.47	.355227	9.77	.644773	14
47	.344912	9.28	.989100	.48	.355813	9.75	.644187	13
48	.345469	9.25	.989071	.48	.356398	9.73	.643602	12
49	.346024	9.25	.989042	.47	.356982	9.73	.643018	11
50	9.346579	9.25	9.989014	.48	9.357566	9.72	0.642434	10
51	.347134	9.22	.988985	.48	.358149	9.70	.641851	9
52	.347687	9.22	.988956	.48	.358731	9.70	.641269	8
53	.348240	9.20	.988927	.48	.359313	9.67	.640687	7
54	.348792	9.18	.988898	.48	.359893	9.68	.640107	6
55	9.349343	9.17	9.988869	.48	9.360474	9.65	0.639526	5
56	.349893	9.17	.988840	.48	.361053	9.65	.638947	4
57	.350443	9.15	.988811	.48	.361632	9.63	.638368	3
58	.350992	9.13	.988782	.48	.362210	9.62	.637790	2
59	.351540	9.13	.988753	.48	.362787	9.62	.637213	1
60	9.352088		9.988724		9.363364		0.636636	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.352088	9.12	9.988724	.48	9.363364	9.60	0.636636	60
1	.352635	9.10	.988695	.48	.363940	9.58	.636060	59
2	.353181	9.08	.988666	.50	.364515	9.58	.635485	58
3	.353726	9.08	.988636	.48	.365090	9.57	.634910	57
4	.354271	9.07	.988607	.48	.365664	9.55	.634336	56
5	9.354815	9.05	9.988578	.50	9.366237	9.55	0.633763	55
6	.355358	9.05	.988548	.48	.366810	9.53	.633190	54
7	.355901	9.03	.988519	.50	.367382	9.52	.632618	53
8	.356443	9.02	.988489	.48	.367953	9.52	.632047	52
9	.356984	9.00	.988460	.50	.368524	9.50	.631476	51
10	9.357524	9.00	9.988430	.48	9.369094	9.48	0.630906	50
11	.358064	8.98	.988401	.50	.369663	9.48	.630337	49
12	.358603	8.97	.988371	.48	.370232	9.45	.629768	48
13	.359141	8.95	.988342	.50	.370799	9.47	.629201	47
14	.359678	8.95	.988312	.50	.371367	9.43	.628633	46
15	9.360215	8.95	9.988282	.50	9.371933	9.43	0.628067	45
16	.360752	8.92	.988252	.48	.372499	9.42	.627501	44
17	.361287	8.92	.988223	.50	.373064	9.42	.626936	43
18	.361822	8.90	.988193	.50	.373629	9.40	.626371	42
19	.362356	8.88	.988163	.50	.374193	9.38	.625807	41
20	9.362889	8.88	9.988133	.50	9.374756	9.38	0.625244	40
21	.363422	8.87	.988103	.50	.375319	9.37	.624681	39
22	.363954	8.85	.988073	.50	.375881	9.35	.624119	38
23	.364485	8.85	.988043	.50	.376442	9.35	.623558	37
24	.365016	8.83	.988013	.50	.377003	9.33	.622997	36
25	9.365546	8.82	9.987983	.50	9.377563	9.32	0.622437	35
26	.366075	8.82	.987953	.52	.378122	9.32	.621878	34
27	.366604	8.78	.987922	.50	.378681	9.30	.621319	33
28	.367131	8.80	.987892	.50	.379239	9.30	.620761	32
29	.367659	8.77	.987862	.50	.379797	9.28	.620203	31
30	9.368185	8.77	9.987832	.52	9.380354	9.27	0.619646	30
31	.368711	8.75	.987801	.50	.380910	9.27	.619090	29
32	.369236	8.75	.987771	.52	.381466	9.23	.618534	28
33	.369761	8.73	.987740	.50	.382020	9.25	.617980	27
34	.370285	8.72	.987710	.52	.382575	9.23	.617425	26
35	9.370808	8.70	9.987679	.50	9.383129	9.22	0.616871	25
36	.371330	8.70	.987649	.52	.383682	9.20	.616318	24
37	.371852	8.68	.987618	.50	.384234	9.20	.615766	23
38	.372373	8.68	.987588	.52	.384786	9.18	.615214	22
39	.372894	8.67	.987557	.52	.385337	9.18	.614663	21
40	9.373414	8.65	9.987526	.50	9.385888	9.17	0.614112	20
41	.373933	8.65	.987496	.52	.386438	9.15	.613562	19
42	.374452	8.63	.987465	.52	.386987	9.15	.613013	18
43	.374970	8.62	.987434	.52	.387536	9.13	.612464	17
44	.375487	8.60	.987403	.52	.388084	9.12	.611916	16
45	9.376003	8.60	9.987372	.52	9.388631	9.12	0.611369	15
46	.376519	8.60	.987341	.52	.389178	9.10	.610822	14
47	.377035	8.57	.987310	.52	.389724	9.10	.610276	13
48	.377549	8.57	.987279	.52	.390270	9.08	.609730	12
49	.378063	8.57	.987248	.52	.390815	9.08	.609185	11
50	9.378577	8.53	9.987217	.52	9.391360	9.05	0.608640	10
51	.379089	8.53	.987186	.52	.391903	9.07	.608097	9
52	.379601	8.53	.987155	.52	.392447	9.03	.607553	8
53	.380113	8.52	.987124	.53	.392989	9.03	.607011	7
54	.380624	8.50	.987092	.52	.393531	9.03	.606469	6
55	9.381134	8.48	9.987061	.52	9.394073	9.02	0.605927	5
56	.381643	8.48	.987030	.53	.394614	9.00	.605386	4
57	.382152	8.48	.986998	.52	.395154	9.00	.604846	3
58	.382661	8.45	.986967	.52	.395694	8.98	.604306	2
59	.383168	8.45	.986936	.53	.396233	8.97	.603767	1
60	9.383675		9.986904		9.396771		0.603229	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.383675	8.45	9.986904	.52	9.396771	8.97	0.603229	60
1	.384182	8.42	.986873	.53	.397309	8.95	.602691	59
2	.384687	8.42	.986841	.53	.397846	8.95	.602154	58
3	.385192	8.42	.986809	.52	.398383	8.93	.601617	57
4	.385697	8.40	.986778	.53	.398919	8.93	.601081	56
5	9.386201	8.38	9.986746	.53	9.399455	8.92	0.600545	55
6	.386704	8.38	.986714	.52	.399990	8.90	.600010	54
7	.387207	8.37	.986683	.53	.400524	8.90	.599476	53
8	.387709	8.35	.986651	.53	.401058	8.88	.598942	52
9	.388210	8.35	.986619	.53	.401591	8.88	.598409	51
10	9.388711	8.33	9.986587	.53	9.402124	8.87	0.597876	50
11	.389211	8.33	.986555	.53	.402656	8.85	.597344	49
12	.389711	8.32	.986523	.53	.403187	8.85	.596813	48
13	.390210	8.30	.986491	.53	.403718	8.85	.596282	47
14	.390708	8.30	.986459	.53	.404249	8.82	.595751	46
15	9.391206	8.28	9.986427	.53	9.404778	8.83	0.595222	45
16	.391703	8.27	.986395	.53	.405308	8.80	.594692	44
17	.392199	8.27	.986363	.53	.405836	8.80	.594164	43
18	.392695	8.27	.986331	.53	.406364	8.80	.593636	42
19	.393191	8.23	.986299	.55	.406892	8.78	.593108	41
20	9.393685	8.23	9.986266	.53	9.407419	8.77	0.592581	40
21	.394179	8.23	.986234	.53	.407945	8.77	.592055	39
22	.394673	8.22	.986202	.55	.408471	8.75	.591529	38
23	.395166	8.20	.986169	.53	.408996	8.75	.591004	37
24	.395658	8.20	.986137	.55	.409521	8.73	.590479	36
25	9.396150	8.18	9.986104	.53	9.410045	8.73	0.589955	35
26	.396641	8.18	.986072	.55	.410569	8.72	.589431	34
27	.397132	8.15	.986039	.53	.411092	8.72	.588908	33
28	.397621	8.17	.986007	.55	.411615	8.70	.588385	32
29	.398111	8.15	.985974	.53	.412137	8.68	.587863	31
30	9.398600	8.13	9.985942	.55	9.412658	8.68	0.587342	30
31	.399088	8.12	.985909	.55	.413179	8.67	.586821	29
32	.399575	8.12	.985876	.55	.413699	8.67	.586301	28
33	.400062	8.12	.985843	.53	.414219	8.65	.585781	27
34	.400549	8.10	.985811	.55	.414738	8.65	.585262	26
35	9.401035	8.08	9.985778	.55	9.415257	8.63	0.584743	25
36	.401520	8.08	.985745	.55	.415775	8.63	.584225	24
37	.402005	8.07	.985712	.55	.416293	8.62	.583707	23
38	.402489	8.05	.985679	.55	.416810	8.60	.583190	22
39	.402972	8.05	.985646	.55	.417326	8.60	.582674	21
40	9.403455	8.05	9.985613	.55	9.417842	8.60	0.582158	20
41	.403938	8.03	.985580	.55	.418358	8.58	.581642	19
42	.404420	8.02	.985547	.55	.418873	8.57	.581127	18
43	.404901	8.02	.985514	.57	.419387	8.57	.580613	17
44	.405382	8.00	.985480	.55	.419901	8.57	.580099	16
45	9.405862	7.98	9.985447	.55	9.420415	8.53	0.579585	15
46	.406341	7.98	.985414	.55	.420927	8.55	.579073	14
47	.406820	7.98	.985381	.57	.421440	8.53	.578560	13
48	.407299	7.97	.985347	.55	.421952	8.52	.578048	12
49	.407777	7.95	.985314	.57	.422463	8.52	.577537	11
50	9.408254	7.95	9.985280	.55	9.422974	8.50	0.577026	10
51	.408731	7.93	.985247	.57	.423484	8.48	.576516	9
52	.409207	7.92	.985213	.55	.423993	8.50	.576007	8
53	.409682	7.92	.985180	.57	.424503	8.47	.575497	7
54	.410157	7.92	.985146	.55	.425011	8.47	.574989	6
55	9.410632	7.90	9.985113	.57	9.425519	8.47	0.574481	5
56	.411106	7.88	.985079	.57	.426027	8.45	.573973	4
57	.411579	7.88	.985045	.57	.426534	8.45	.573466	3
58	.412052	7.87	.985011	.55	.427041	8.43	.572959	2
59	.412524	7.87	.984978	.57	.427547	8.42	.572453	1
60	9.412996		9.984944		9.428052		0.571948	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.412996	7.85	9.984944	.57	9.428052	8.43	0.571948	60
1	.413467	7.85	.984910	.57	.428558	8.40	.571442	59
2	.413938	7.83	.984876	.57	.429062	8.40	.570938	58
3	.414408	7.83	.984842	.57	.429566	8.40	.570434	57
4	.414878	7.82	.984808	.57	.430070	8.38	.569930	56
5	9.415347	7.80	9.984774	.57	9.430573	8.37	0.569427	55
6	.415815	7.80	.984740	.57	.431075	8.37	.568925	54
7	.416283	7.80	.984706	.57	.431577	8.37	.568423	53
8	.416751	7.77	.984672	.57	.432079	8.35	.567921	52
9	.417217	7.78	.984638	.58	.432580	8.33	.567420	51
10	9.417684	7.77	9.984603	.57	9.433080	8.33	0.566920	50
11	.418150	7.75	.984569	.57	.433580	8.33	.566420	49
12	.418615	7.73	.984535	.58	.434080	8.32	.565920	48
13	.419079	7.75	.984500	.57	.434579	8.32	.565421	47
14	.419544	7.72	.984466	.57	.435078	8.30	.564922	46
15	9.420007	7.72	9.984432	.58	9.435576	8.28	0.564424	45
16	.420470	7.72	.984397	.57	.436073	8.28	.563927	44
17	.420933	7.70	.984363	.58	.436570	8.28	.563430	43
18	.421395	7.70	.984328	.57	.437067	8.27	.562933	42
19	.421857	7.68	.984294	.58	.437563	8.27	.562437	41
20	9.422318	7.67	9.984259	.58	9.438059	8.25	0.561941	40
21	.422778	7.67	.984224	.57	.438554	8.23	.561446	39
22	.423238	7.65	.984190	.58	.439048	8.25	.560952	38
23	.423697	7.65	.984155	.58	.439543	8.22	.560457	37
24	.424156	7.65	.984120	.58	.440036	8.22	.559964	36
25	9.424615	7.63	9.984085	.58	9.440529	8.22	0.559471	35
26	.425073	7.62	.984050	.58	.441022	8.20	.558978	34
27	.425530	7.62	.984015	.57	.441514	8.20	.558486	33
28	.425987	7.60	.983981	.58	.442006	8.18	.557994	32
29	.426443	7.60	.983946	.58	.442497	8.18	.557503	31
30	9.426899	7.58	9.983911	.60	9.442988	8.18	0.557012	30
31	.427354	7.58	.983875	.58	.443479	8.15	.556521	29
32	.427809	7.57	.983840	.58	.443968	8.17	.556032	28
33	.428263	7.57	.983805	.58	.444458	8.15	.555542	27
34	.428717	7.55	.983770	.58	.444947	8.13	.555053	26
35	9.429170	7.55	9.983735	.58	9.445435	8.13	0.554565	25
36	.429623	7.53	.983700	.60	.445923	8.13	.554077	24
37	.430075	7.53	.983664	.58	.446411	8.12	.553589	23
38	.430527	7.52	.983629	.58	.446898	8.10	.553102	22
39	.430978	7.52	.983594	.60	.447384	8.10	.552616	21
40	9.431429	7.50	9.983558	.58	9.447870	8.10	0.552130	20
41	.431879	7.50	.983523	.60	.448356	8.08	.551644	19
42	.432329	7.48	.983487	.58	.448841	8.08	.551159	18
43	.432778	7.47	.983452	.60	.449326	8.07	.550674	17
44	.433226	7.48	.983416	.58	.449810	8.07	.550190	16
45	9.433675	7.45	9.983381	.60	9.450294	8.05	0.549706	15
46	.434122	7.45	.983345	.60	.450777	8.05	.549223	14
47	.434569	7.45	.983309	.60	.451260	8.05	.548740	13
48	.435016	7.43	.983273	.58	.451743	8.03	.548257	12
49	.435462	7.43	.983238	.60	.452225	8.02	.547775	11
50	9.435908	7.42	9.983202	.60	9.452706	8.02	0.547294	10
51	.436353	7.42	.983166	.60	.453187	8.02	.546813	9
52	.436798	7.40	.983130	.60	.453668	8.00	.546332	8
53	.437242	7.40	.983094	.60	.454148	8.00	.545852	7
54	.437686	7.38	.983058	.60	.454628	7.98	.545372	6
55	9.438129	7.38	9.983022	.60	9.455107	7.98	0.544893	5
56	.438572	7.37	.982986	.60	.455586	7.97	.544414	4
57	.439014	7.37	.982950	.60	.456064	7.97	.543936	3
58	.439456	7.35	.982914	.60	.456542	7.95	.543458	2
59	.439897	7.35	.982878	.60	.457019	7.95	.542981	1
60	9.440338		9.982842		9.457496		0.542504	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.440338	7.33	9.982842	.62	9.457496	7.95	0.542504	60
1	.440778	7.33	.982805	.60	.457973	7.93	.542027	59
2	.441218	7.33	.982769	.60	.458449	7.93	.541551	58
3	.441658	7.30	.982733	.62	.458925	7.92	.541075	57
4	.442096	7.32	.982696	.60	.459400	7.92	.540600	56
5	9.442535	7.30	9.982660	.60	9.459875	7.90	0.540125	55
6	.442973	7.28	.982624	.62	.460349	7.90	.539651	54
7	.443410	7.28	.982587	.60	.460823	7.90	.539177	53
8	.443847	7.28	.982551	.62	.461297	7.88	.538703	52
9	.444284	7.27	.982514	.62	.461770	7.87	.538230	51
10	9.444720	7.25	9.982477	.60	9.462242	7.88	0.537758	50
11	.445155	7.25	.982441	.62	.462715	7.85	.537285	49
12	.445590	7.25	.982404	.62	.463186	7.87	.536814	48
13	.446025	7.23	.982367	.60	.463658	7.83	.536342	47
14	.446459	7.23	.982331	.62	.464128	7.85	.535872	46
15	9.446893	7.22	9.982294	.62	9.464599	7.83	0.535401	45
16	.447326	7.22	.982257	.62	.465069	7.83	.534931	44
17	.447759	7.20	.982220	.62	.465539	7.82	.534461	43
18	.448191	7.20	.982183	.62	.466008	7.82	.533992	42
19	.448623	7.18	.982146	.62	.466477	7.80	.533523	41
20	9.449054	7.18	9.982109	.62	9.466945	7.80	0.533055	40
21	.449485	7.17	.982072	.62	.467413	7.78	.532587	39
22	.449915	7.17	.982035	.62	.467880	7.78	.532120	38
23	.450345	7.17	.981998	.62	.468347	7.78	.531653	37
24	.450775	7.15	.981961	.62	.468814	7.77	.531186	36
25	9.451204	7.13	9.981924	.63	9.469280	7.77	0.530720	35
26	.451632	7.13	.981886	.62	.469746	7.75	.530254	34
27	.452060	7.13	.981849	.62	.470211	7.75	.529789	33
28	.452488	7.12	.981812	.63	.470676	7.75	.529324	32
29	.452915	7.12	.981774	.62	.471141	7.73	.528859	31
30	9.453342	7.10	9.981737	.62	9.471605	7.73	0.528395	30
31	.453768	7.10	.981700	.63	.472069	7.72	.527931	29
32	.454194	7.08	.981662	.62	.472532	7.72	.527468	28
33	.454619	7.08	.981625	.63	.472995	7.70	.527005	27
34	.455044	7.08	.981587	.63	.473457	7.70	.526543	26
35	9.455469	7.07	9.981549	.62	9.473919	7.70	0.526081	25
36	.455893	7.05	.981512	.63	.474381	7.68	.525619	24
37	.456316	7.05	.981474	.63	.474842	7.68	.525158	23
38	.456739	7.05	.981436	.62	.475303	7.67	.524697	22
39	.457162	7.03	.981399	.63	.475763	7.67	.524237	21
40	9.457584	7.03	9.981361	.63	9.476223	7.67	0.523777	20
41	.458006	7.02	.981323	.63	.476683	7.65	.523317	19
42	.458427	7.02	.981285	.63	.477142	7.65	.522858	18
43	.458848	7.00	.981247	.63	.477601	7.63	.522399	17
44	.459268	7.00	.981209	.63	.478059	7.63	.521941	16
45	9.459688	7.00	9.981171	.63	9.478517	7.63	0.521483	15
46	.460108	6.98	.981133	.63	.478975	7.62	.521025	14
47	.460527	6.98	.981095	.63	.479432	7.62	.520568	13
48	.460946	6.97	.981057	.63	.479889	7.60	.520111	12
49	.461364	6.97	.981019	.63	.480345	7.60	.519655	11
50	9.461782	6.95	9.980981	.65	9.480801	7.60	0.519199	10
51	.462199	6.95	.980942	.63	.481257	7.58	.518743	9
52	.462616	6.93	.980904	.63	.481712	7.58	.518288	8
53	.463032	6.93	.980866	.65	.482167	7.57	.517833	7
54	.463448	6.93	.980827	.63	.482621	7.57	.517379	6
55	9.463864	6.92	9.980789	.65	9.483075	7.57	0.516925	5
56	.464279	6.92	.980750	.63	.483529	7.55	.516471	4
57	.464694	6.90	.980712	.65	.483982	7.55	.516018	3
58	.465108	6.90	.980673	.63	.484435	7.53	.515565	2
59	.465522	6.88	.980635	.65	.484887	7.53	.515113	1
60	9.465935		9.980596		9.485339		0.514661	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.465935	6.88	9.980596	.63	9.485339	7.53	0.514661	60
1	.466348	6.88	.980558	.65	.485791	7.52	.514209	59
2	.466761	6.87	.980519	.65	.486242	7.52	.513758	58
3	.467173	6.87	.980480	.63	.486693	7.50	.513307	57
4	.467585	6.85	.980442	.65	.487143	7.50	.512857	56
5	9.467996	6.85	9.980403	.65	9.487593	7.50	0.512407	55
6	.468407	6.83	.980364	.65	.488043	7.48	.511957	54
7	.468817	6.83	.980325	.65	.488492	7.48	.511508	53
8	.469227	6.83	.980286	.65	.488941	7.48	.511059	52
9	.469637	6.82	.980247	.65	.489390	7.47	.510610	51
10	9.470046	6.82	9.980208	.65	9.489838	7.47	0.510162	50
11	.470455	6.80	.980169	.65	.490286	7.45	.509714	49
12	.470863	6.80	.980130	.65	.490733	7.45	.509267	48
13	.471271	6.80	.980091	.65	.491180	7.45	.508820	47
14	.471679	6.78	.980052	.67	.491627	7.43	.508373	46
15	9.472086	6.77	9.980012	.65	9.492073	7.43	0.507927	45
16	.472492	6.77	.979973	.65	.492519	7.43	.507481	44
17	.472898	6.77	.979934	.65	.492965	7.42	.507035	43
18	.473304	6.77	.979895	.67	.493410	7.40	.506590	42
19	.473710	6.75	.979855	.65	.493854	7.42	.506146	41
20	9.474115	6.73	9.979816	.67	9.494299	7.40	0.505701	40
21	.474519	6.73	.979776	.65	.494743	7.38	.505257	39
22	.474923	6.73	.979737	.67	.495186	7.40	.504814	38
23	.475327	6.72	.979697	.65	.495630	7.38	.504370	37
24	.475730	6.72	.979658	.67	.496073	7.37	.503927	36
25	9.476133	6.72	9.979618	.65	9.496515	7.37	0.503485	35
26	.476536	6.70	.979579	.67	.496957	7.37	.503043	34
27	.476938	6.70	.979539	.67	.497399	7.37	.502601	33
28	.477340	6.68	.979499	.67	.497841	7.35	.502159	32
29	.477741	6.68	.979459	.65	.498282	7.33	.501718	31
30	9.478142	6.67	9.979420	.67	9.498722	7.35	0.501278	30
31	.478542	6.67	.979380	.67	.499163	7.33	.500837	29
32	.478942	6.67	.979340	.67	.499603	7.32	.500397	28
33	.479342	6.65	.979300	.67	.500042	7.32	.499958	27
34	.479741	6.65	.979260	.67	.500481	7.32	.499519	26
35	9.480140	6.65	9.979220	.67	9.500920	7.32	0.499080	25
36	.480539	6.63	.979180	.67	.501359	7.30	.498641	24
37	.480937	6.62	.979140	.67	.501797	7.30	.498203	23
38	.481334	6.62	.979100	.68	.502235	7.28	.497765	22
39	.481731	6.62	.979059	.67	.502672	7.28	.497328	21
40	9.482128	6.62	9.979019	.67	9.503109	7.28	0.496891	20
41	.482525	6.60	.978979	.67	.503546	7.27	.496454	19
42	.482921	6.58	.978939	.68	.503982	7.27	.496018	18
43	.483316	6.60	.978898	.67	.504418	7.27	.495582	17
44	.483712	6.58	.978858	.68	.504854	7.25	.495146	16
45	9.484107	6.57	9.978817	.67	9.505289	7.25	0.494711	15
46	.484501	6.57	.978777	.67	.505724	7.25	.494276	14
47	.484895	6.57	.978737	.68	.506159	7.23	.493841	13
48	.485289	6.55	.978696	.68	.506593	7.23	.493407	12
49	.485682	6.55	.978655	.67	.507027	7.22	.492973	11
50	9.486075	6.53	9.978615	.68	9.507460	7.22	0.492540	10
51	.486467	6.55	.978574	.68	.507893	7.22	.492107	9
52	.486860	6.52	.978533	.67	.508326	7.22	.491674	8
53	.487251	6.53	.978493	.68	.508759	7.20	.491241	7
54	.487643	6.52	.978452	.68	.509191	7.18	.490809	6
55	9.488034	6.50	9.978411	.68	9.509622	7.20	0.490378	5
56	.488424	6.50	.978370	.68	.510054	7.18	.489946	4
57	.488814	6.50	.978329	.68	.510485	7.18	.489515	3
58	.489204	6.48	.978288	.68	.510916	7.17	.489084	2
59	.489593	6.48	.978247	.68	.511346	7.17	.488654	1
60	9.489982		9.978206		9.511776		0.488224	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.489982	6.48	9.978206	.68	9.511776	7.17	0.488224	60
1	.490371	6.47	.978165	.68	.512206	7.15	.487794	59
2	.490759	6.47	.978124	.68	.512635	7.15	.487365	58
3	.491147	6.47	.978083	.68	.513064	7.15	.486936	57
4	.491535	6.45	.978042	.68	.513493	7.13	.486507	56
5	9.491922	6.43	9.978001	.70	9.513921	7.13	0.486079	55
6	.492308	6.45	.977959	.68	.514349	7.13	.485651	54
7	.492695	6.43	.977918	.68	.514777	7.12	.485223	53
8	.493081	6.42	.977877	.70	.515204	7.12	.484796	52
9	.493466	6.42	.977835	.68	.515631	7.10	.484369	51
10	9.493851	6.42	9.977794	.70	9.516057	7.12	0.483943	50
11	.494236	6.42	.977752	.68	.516484	7.10	.483516	49
12	.494621	6.40	.977711	.70	.516910	7.08	.483090	48
13	.495005	6.38	.977669	.68	.517335	7.10	.482665	47
14	.495388	6.40	.977628	.70	.517761	7.08	.482239	46
15	9.495772	6.37	9.977586	.70	9.518186	7.07	0.481814	45
16	.496154	6.38	.977544	.68	.518610	7.07	.481390	44
17	.496537	6.37	.977503	.70	.519034	7.07	.480966	43
18	.496919	6.37	.977461	.70	.519458	7.07	.480542	42
19	.497301	6.35	.977419	.70	.519882	7.05	.480118	41
20	9.497682	6.37	9.977377	.70	9.520305	7.05	0.479695	40
21	.498064	6.33	.977335	.70	.520728	7.05	.479272	39
22	.498444	6.35	.977293	.70	.521151	7.03	.478849	38
23	.498825	6.32	.977251	.70	.521573	7.03	.478427	37
24	.499204	6.33	.977209	.70	.521995	7.03	.478005	36
25	9.499584	6.32	9.977167	.70	9.522417	7.02	0.477583	35
26	.499963	6.32	.977125	.70	.522838	7.02	.477162	34
27	.500342	6.32	.977083	.70	.523259	7.02	.476741	33
28	.500721	6.30	.977041	.70	.523680	7.00	.476320	32
29	.501099	6.28	.976999	.70	.524100	7.00	.475900	31
30	9.501476	6.30	9.976957	.72	9.524520	7.00	0.475480	30
31	.501854	6.28	.976914	.70	.524940	6.98	.475060	29
32	.502231	6.27	.976872	.70	.525359	6.98	.474641	28
33	.502607	6.28	.976830	.72	.525778	6.98	.474222	27
34	.502984	6.27	.976787	.70	.526197	6.97	.473803	26
35	9.503360	6.25	9.976745	.72	9.526615	6.97	0.473385	25
36	.503735	6.25	.976702	.70	.527033	6.97	.472967	24
37	.504110	6.25	.976660	.72	.527451	6.95	.472549	23
38	.504485	6.25	.976617	.72	.527868	6.95	.472132	22
39	.504860	6.23	.976574	.70	.528285	6.95	.471715	21
40	9.505234	6.23	9.976532	.72	9.528702	6.95	0.471298	20
41	.505608	6.22	.976489	.72	.529119	6.93	.470881	19
42	.505981	6.22	.976446	.70	.529535	6.93	.470465	18
43	.506354	6.22	.976404	.72	.529951	6.92	.470049	17
44	.506727	6.20	.976361	.72	.530366	6.92	.469634	16
45	9.507099	6.20	9.976318	.72	9.530781	6.92	0.469219	15
46	.507471	6.20	.976275	.72	.531196	6.92	.468804	14
47	.507843	6.18	.976232	.72	.531611	6.90	.468389	13
48	.508214	6.18	.976189	.72	.532025	6.90	.467975	12
49	.508585	6.18	.976146	.72	.532439	6.90	.467561	11
50	9.508956	6.17	9.976103	.72	9.532853	6.88	0.467147	10
51	.509326	6.17	.976060	.72	.533266	6.88	.466734	9
52	.509696	6.15	.976017	.72	.533679	6.88	.466321	8
53	.510065	6.15	.975974	.73	.534092	6.87	.465908	7
54	.510434	6.15	.975930	.72	.534504	6.87	.465496	6
55	9.510803	6.15	9.975887	.72	9.534916	6.87	0.465084	5
56	.511172	6.13	.975844	.73	.535328	6.85	.464672	4
57	.511540	6.12	.975800	.72	.535739	6.85	.464261	3
58	.511907	6.13	.975757	.72	.536150	6.85	.463850	2
59	.512275	6.12	.975714	.73	.536561	6.85	.463439	1
60	9.512642		9.975670		9.536972		0.463028	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.512642	6.12	9.975670	.72	9.536972	6.83	0.463028	60
1	.513009	6.10	.975627	.73	.537382	6.83	.462618	59
2	.513375	6.10	.975583	.73	.537792	6.83	.462208	58
3	.513741	6.10	.975539	.72	.538202	6.82	.461798	57
4	.514107	6.08	.975496	.73	.538611	6.82	.461389	56
5	9.514472	6.08	9.975452	.73	9.539020	6.82	0.460980	55
6	.514837	6.08	.975408	.72	.539429	6.80	.460571	54
7	.515202	6.07	.975365	.73	.539837	6.80	.460163	53
8	.515566	6.07	.975321	.73	.540245	6.80	.459755	52
9	.515930	6.07	.975277	.73	.540653	6.80	.459347	51
10	9.516294	6.05	9.975233	.73	9.541061	6.78	0.458939	50
11	.516657	6.05	.975189	.73	.541468	6.78	.458532	49
12	.517020	6.03	.975145	.73	.541875	6.77	.458125	48
13	.517382	6.05	.975101	.73	.542281	6.78	.457719	47
14	.517745	6.03	.975057	.73	.542688	6.77	.457312	46
15	9.518107	6.02	9.975013	.73	9.543094	6.75	0.456906	45
16	.518468	6.02	.974969	.73	.543499	6.77	.456501	44
17	.518829	6.02	.974925	.75	.543905	6.75	.456095	43
18	.519190	6.02	.974880	.73	.544310	6.75	.455690	42
19	.519551	6.00	.974836	.73	.544715	6.73	.455285	41
20	9.519911	6.00	9.974792	.73	9.545119	6.75	0.454881	40
21	.520271	6.00	.974748	.75	.545524	6.73	.454476	39
22	.520631	5.98	.974703	.73	.545928	6.72	.454072	38
23	.520990	5.98	.974659	.75	.546331	6.73	.453669	37
24	.521349	5.97	.974614	.73	.546735	6.72	.453265	36
25	9.521707	5.98	9.974570	.75	9.547138	6.70	0.452862	35
26	.522066	5.97	.974525	.73	.547540	6.72	.452460	34
27	.522424	5.95	.974481	.75	.547943	6.70	.452057	33
28	.522781	5.95	.974436	.75	.548345	6.70	.451655	32
29	.523138	5.95	.974391	.73	.548747	6.70	.451253	31
30	9.523495	5.95	9.974347	.75	9.549149	6.68	0.450851	30
31	.523852	5.93	.974302	.75	.549550	6.68	.450450	29
32	.524208	5.93	.974257	.75	.549951	6.68	.450049	28
33	.524564	5.93	.974212	.75	.550352	6.67	.449648	27
34	.524920	5.92	.974167	.75	.550752	6.68	.449248	26
35	9.525275	5.92	9.974122	.75	9.551153	6.65	0.448847	25
36	.525630	5.90	.974077	.75	.551552	6.67	.448448	24
37	.525984	5.92	.974032	.75	.551952	6.65	.448048	23
38	.526339	5.90	.973987	.75	.552351	6.65	.447649	22
39	.526693	5.88	.973942	.75	.552750	6.65	.447250	21
40	9.527046	5.90	9.973897	.75	9.553149	6.65	0.446851	20
41	.527400	5.88	.973852	.75	.553548	6.63	.446452	19
42	.527753	5.87	.973807	.77	.553946	6.63	.446054	18
43	.528105	5.88	.973761	.75	.554344	6.62	.445656	17
44	.528458	5.87	.973716	.75	.554741	6.63	.445259	16
45	9.528810	5.85	9.973671	.77	9.555139	6.62	0.444861	15
46	.529161	5.87	.973625	.75	.555536	6.62	.444464	14
47	.529513	5.85	.973580	.75	.555933	6.60	.444067	13
48	.529864	5.85	.973535	.77	.556329	6.60	.443671	12
49	.530215	5.83	.973489	.75	.556725	6.60	.443275	11
50	9.530565	5.83	9.973444	.77	9.557121	6.60	0.442879	10
51	.530915	5.83	.973398	.77	.557517	6.60	.442483	9
52	.531265	5.82	.973352	.75	.557913	6.58	.442087	8
53	.531614	5.82	.973307	.77	.558308	6.58	.441692	7
54	.531963	5.82	.973261	.77	.558703	6.57	.441297	6
55	9.532312	5.82	9.973215	.77	9.559097	6.57	0.440903	5
56	.532661	5.80	.973169	.75	.559491	6.57	.440509	4
57	.533009	5.80	.973124	.77	.559885	6.57	.440115	3
58	.533357	5.78	.973078	.77	.560279	6.57	.439721	2
59	.533704	5.80	.973032	.77	.560673	6.55	.439327	1
60	9.534052		9.972986		9.561066		0.438934	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.534052	5.78	9.972986	.77	9.561066	6.55	0.438934	60
1	.534399	5.77	.972940	.77	.561459	6.53	.438541	59
2	.534745	5.78	.972894	.77	.561851	6.55	.438149	58
3	.535092	5.77	.972848	.77	.562244	6.53	.437756	57
4	.535438	5.75	.972802	.78	.562636	6.53	.437364	56
5	9.535783	5.77	9.972755	.77	9.563028	6.52	0.436972	55
6	.536129	5.75	.972709	.77	.563419	6.53	.436581	54
7	.536474	5.73	.972663	.77	.563811	6.52	.436189	53
8	.536818	5.75	.972617	.78	.564202	6.52	.435798	52
9	.537163	5.73	.972570	.77	.564593	6.50	.435407	51
10	9.537507	5.73	9.972524	.77	9.564983	6.50	0.435017	50
11	.537851	5.72	.972478	.78	.565373	6.50	.434627	49
12	.538194	5.73	.972431	.77	.565763	6.50	.434237	48
13	.538538	5.70	.972385	.78	.566153	6.48	.433847	47
14	.538880	5.72	.972338	.78	.566542	6.50	.433458	46
15	9.539223	5.70	9.972291	.77	9.566932	6.47	0.433068	45
16	.539565	5.70	.972245	.78	.567320	6.48	.432680	44
17	.539907	5.70	.972198	.78	.567709	6.48	.432291	43
18	.540249	5.68	.972151	.77	.568098	6.47	.431902	42
19	.540590	5.68	.972105	.78	.568486	6.45	.431514	41
20	9.540931	5.68	9.972058	.78	9.568873	6.47	0.431127	40
21	.541272	5.68	.972011	.78	.569261	6.45	.430739	39
22	.541613	5.67	.971964	.78	.569648	6.45	.430352	38
23	.541953	5.67	.971917	.78	.570035	6.45	.429965	37
24	.542293	5.65	.971870	.78	.570422	6.45	.429578	36
25	9.542632	5.65	9.971823	.78	9.570809	6.43	0.429191	35
26	.542971	5.65	.971776	.78	.571195	6.43	.428805	34
27	.543310	5.65	.971729	.78	.571581	6.43	.428419	33
28	.543649	5.63	.971682	.78	.571967	6.42	.428033	32
29	.543987	5.63	.971635	.78	.572352	6.43	.427648	31
30	9.544325	5.63	9.971588	.80	9.572738	6.42	0.427262	30
31	.544663	5.62	.971540	.78	.573123	6.40	.426877	29
32	.545000	5.63	.971493	.78	.573507	6.42	.426493	28
33	.545338	5.60	.971446	.80	.573892	6.40	.426108	27
34	.545674	5.62	.971398	.78	.574276	6.40	.425724	26
35	9.546011	5.60	9.971351	.80	9.574660	6.40	0.425340	25
36	.546347	5.60	.971303	.78	.575044	6.38	.424956	24
37	.546683	5.60	.971256	.80	.575427	6.38	.424573	23
38	.547019	5.58	.971208	.78	.575810	6.38	.424190	22
39	.547354	5.58	.971161	.80	.576193	6.38	.423807	21
40	9.547689	5.58	9.971113	.78	9.576576	6.38	0.423424	20
41	.548024	5.58	.971066	.80	.576959	6.37	.423041	19
42	.548359	5.57	.971018	.80	.577341	6.37	.422659	18
43	.548693	5.57	.970970	.80	.577723	6.35	.422277	17
44	.549027	5.55	.970922	.80	.578104	6.37	.421896	16
45	9.549360	5.55	9.970874	.78	9.578486	6.35	0.421514	15
46	.549693	5.55	.970827	.80	.578867	6.35	.421133	14
47	.550026	5.55	.970779	.80	.579248	6.35	.420752	13
48	.550359	5.55	.970731	.80	.579629	6.33	.420371	12
49	.550692	5.53	.970683	.80	.580009	6.33	.419991	11
50	9.551024	5.53	9.970635	.82	9.580389	6.33	0.419611	10
51	.551356	5.52	.970586	.80	.580769	6.33	.419231	9
52	.551687	5.52	.970538	.80	.581149	6.32	.418851	8
53	.552018	5.52	.970490	.80	.581528	6.32	.418472	7
54	.552349	5.52	.970442	.80	.581907	6.32	.418093	6
55	9.552680	5.50	9.970394	.82	9.582286	6.32	0.417714	5
56	.553010	5.52	.970345	.80	.582665	6.32	.417335	4
57	.553341	5.48	.970297	.80	.583044	6.30	.416956	3
58	.553670	5.50	.970249	.82	.583422	6.30	.416578	2
59	.554000	5.48	.970200	.80	.583800	6.28	.416200	1
60	9.554329		9.970152		9.584177		0.415823	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.554329	5.48	9.970152	.82	9.584177	6.30	0.415823	60
1	.554658	5.48	.970103	.80	.584555	6.28	.415445	59
2	.554987	5.47	.970055	.82	.584932	6.28	.415068	58
3	.555315	5.47	.970006	.82	.585309	6.28	.414691	57
4	.555643	5.47	.969957	.80	.585686	6.27	.414314	56
5	9.555971	5.47	9.969909	.82	9.586062	6.28	0.413938	55
6	.556299	5.45	.969860	.82	.586439	6.27	.413561	54
7	.556626	5.45	.969811	.82	.586815	6.25	.413185	53
8	.556953	5.45	.969762	.80	.587190	6.27	.412810	52
9	.557280	5.43	.969714	.82	.587566	6.25	.412434	51
10	9.557606	5.43	9.969665	.82	9.587941	6.25	0.412059	50
11	.557932	5.43	.969616	.82	.588316	6.25	.411684	49
12	.558258	5.42	.969567	.82	.588691	6.25	.411309	48
13	.558583	5.43	.969518	.82	.589066	6.23	.410934	47
14	.558909	5.42	.969469	.82	.589440	6.23	.410560	46
15	9.559234	5.40	9.969420	.83	9.589814	6.23	0.410186	45
16	.559558	5.42	.969370	.82	.590188	6.23	.409812	44
17	.559883	5.40	.969321	.82	.590562	6.22	.409438	43
18	.560207	5.40	.969272	.82	.590935	6.22	.409065	42
19	.560531	5.40	.969223	.83	.591308	6.22	.408692	41
20	9.560855	5.38	9.969173	.82	9.591681	6.22	0.408319	40
21	.561178	5.38	.969124	.82	.592054	6.20	.407946	39
22	.561501	5.38	.969075	.83	.592426	6.22	.407574	38
23	.561824	5.37	.969025	.82	.592799	6.20	.407201	37
24	.562146	5.37	.968976	.83	.593171	6.18	.406829	36
25	9.562468	5.37	9.968926	.82	9.593542	6.20	0.406458	35
26	.562790	5.37	.968877	.83	.593914	6.18	.406086	34
27	.563112	5.35	.968827	.83	.594285	6.18	.405715	33
28	.563433	5.37	.968777	.82	.594656	6.18	.405344	32
29	.563755	5.33	.968728	.83	.595027	6.18	.404973	31
30	9.564075	5.35	9.968678	.83	9.595398	6.17	0.404602	30
31	.564396	5.33	.968628	.83	.595768	6.17	.404232	29
32	.564716	5.33	.968578	.83	.596138	6.17	.403862	28
33	.565036	5.33	.968528	.82	.596508	6.17	.403492	27
34	.565356	5.33	.968479	.83	.596878	6.15	.403122	26
35	9.565676	5.32	9.968429	.83	9.597247	6.15	0.402753	25
36	.565995	5.32	.968379	.83	.597616	6.15	.402384	24
37	.566314	5.30	.968329	.85	.597985	6.15	.402015	23
38	.566632	5.32	.968278	.83	.598354	6.13	.401646	22
39	.566951	5.30	.968228	.83	.598722	6.15	.401278	21
40	9.567269	5.30	9.968178	.83	9.599091	6.13	0.400909	20
41	.567587	5.28	.968128	.83	.599459	6.13	.400541	19
42	.567904	5.30	.968078	.85	.599827	6.12	.400173	18
43	.568222	5.28	.968027	.83	.600194	6.13	.399806	17
44	.568539	5.28	.967977	.83	.600562	6.12	.399438	16
45	9.568856	5.27	9.967927	.85	9.600929	6.12	0.399071	15
46	.569172	5.27	.967876	.83	.601296	6.12	.398704	14
47	.569488	5.27	.967826	.85	.601663	6.10	.398337	13
48	.569804	5.27	.967775	.83	.602029	6.10	.397971	12
49	.570120	5.25	.967725	.85	.602395	6.10	.397605	11
50	9.570435	5.27	9.967674	.83	9.602761	6.10	0.397239	10
51	.570751	5.25	.967624	.85	.603127	6.10	.396873	9
52	.571066	5.23	.967573	.85	.603493	6.08	.396507	8
53	.571380	5.25	.967522	.85	.603858	6.08	.396142	7
54	.571695	5.23	.967471	.83	.604223	6.08	.395777	6
55	9.572009	5.23	9.967421	.85	9.604588	6.08	0.395412	5
56	.572323	5.22	.967370	.85	.604953	6.07	.395047	4
57	.572636	5.23	.967319	.85	.605317	6.08	.394683	3
58	.572950	5.22	.967268	.85	.605682	6.07	.394318	2
59	.573263	5.20	.967217	.85	.606046	6.07	.393954	1
60	9.573575		9.967166		9.606410		0.393590	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.573575	5.22	9.967166	.85	9.606410	6.05	0.393590	60
1	.573888	5.20	.967115	.85	.606773	6.07	.393227	59
2	.574200	5.20	.967064	.85	.607137	6.05	.392863	58
3	.574512	5.20	.967013	.87	.607500	6.05	.392500	57
4	.574824	5.20	.966961	.85	.607863	6.03	.392137	56
5	9.575136	5.18	9.966910	.85	9.608225	6.05	0.391775	55
6	.575447	5.18	.966859	.85	.608588	6.03	.391412	54
7	.575758	5.18	.966808	.87	.608950	6.03	.391050	53
8	.576069	5.17	.966756	.85	.609312	6.03	.390688	52
9	.576379	5.17	.966705	.87	.609674	6.03	.390326	51
10	9.576689	5.17	9.966653	.85	9.610036	6.02	0.389964	50
11	.576999	5.17	.966602	.87	.610397	6.03	.389603	49
12	.577309	5.15	.966550	.85	.610759	6.02	.389241	48
13	.577618	5.15	.966499	.87	.611120	6.00	.388880	47
14	.577927	5.15	.966447	.87	.611480	6.02	.388520	46
15	9.578236	5.15	9.966395	.85	9.611841	6.00	0.388159	45
16	.578545	5.13	.966344	.87	.612201	6.00	.387799	44
17	.578853	5.15	.966292	.87	.612561	6.00	.387439	43
18	.579162	5.13	.966240	.87	.612921	6.00	.387079	42
19	.579470	5.12	.966188	.87	.613281	6.00	.386719	41
20	9.579777	5.13	9.966136	.85	9.613641	5.98	0.386359	40
21	.580085	5.12	.966085	.87	.614000	5.98	.386000	39
22	.580392	5.12	.966033	.87	.614359	5.98	.385641	38
23	.580699	5.10	.965981	.87	.614718	5.98	.385282	37
24	.581005	5.12	.965929	.88	.615077	5.97	.384923	36
25	9.581312	5.10	9.965876	.87	9.615435	5.97	0.384565	35
26	.581618	5.10	.965824	.87	.615793	5.97	.384207	34
27	.581924	5.08	.965772	.87	.616151	5.97	.383849	33
28	.582229	5.10	.965720	.87	.616509	5.97	.383491	32
29	.582535	5.08	.965668	.88	.616867	5.95	.383133	31
30	9.582840	5.08	9.965615	.87	9.617224	5.97	0.382776	30
31	.583145	5.07	.965563	.87	.617582	5.95	.382418	29
32	.583449	5.08	.965511	.88	.617939	5.93	.382061	28
33	.583754	5.07	.965458	.87	.618295	5.95	.381705	27
34	.584058	5.05	.965406	.88	.618652	5.93	.381348	26
35	9.584361	5.07	9.965353	.87	9.619008	5.93	0.380992	25
36	.584665	5.05	.965301	.88	.619364	5.93	.380636	24
37	.584968	5.07	.965248	.88	.619720	5.93	.380280	23
38	.585272	5.03	.965195	.87	.620076	5.93	.379924	22
39	.585574	5.05	.965143	.88	.620432	5.92	.379568	21
40	9.585877	5.03	9.965090	.88	9.620787	5.92	0.379213	20
41	.586179	5.05	.965037	.88	.621142	5.92	.378858	19
42	.586482	5.02	.964984	.88	.621497	5.92	.378503	18
43	.586783	5.03	.964931	.87	.621852	5.92	.378148	17
44	.587085	5.02	.964879	.88	.622207	5.90	.377793	16
45	9.587386	5.03	9.964826	.88	9.622561	5.90	0.377439	15
46	.587688	5.02	.964773	.88	.622915	5.90	.377085	14
47	.587989	5.00	.964720	.90	.623269	5.90	.376731	13
48	.588289	5.02	.964666	.88	.623623	5.88	.376377	12
49	.588590	5.00	.964613	.88	.623976	5.90	.376024	11
50	9.588890	5.00	9.964560	.88	9.624330	5.88	0.375670	10
51	.589190	4.98	.964507	.88	.624683	5.88	.375317	9
52	.589489	5.00	.964454	.90	.625036	5.87	.374964	8
53	.589789	4.98	.964400	.88	.625388	5.88	.374612	7
54	.590088	4.98	.964347	.88	.625741	5.87	.374259	6
55	9.590387	4.98	9.964294	.90	9.626093	5.87	0.373907	5
56	.590686	4.97	.964240	.88	.626445	5.87	.373555	4
57	.590984	4.97	.964187	.90	.626797	5.87	.373203	3
58	.591282	4.97	.964133	.88	.627149	5.87	.372851	2
59	.591580	4.97	.964080	.90	.627501	5.85	.372499	1
60	9.591878		9.964026		9.627852		0.372148	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.591878	4.97	9.964026	.90	9.627852	5.85	0.372148	60
1	.592176	4.95	.963972	.88	.628203	5.85	.371797	59
2	.592473	4.95	.963919	.90	.628554	5.85	.371446	58
3	.592770	4.95	.963865	.90	.628905	5.83	.371095	57
4	.593067	4.93	.963811	.90	.629255	5.85	.370745	56
5	9.593363	4.93	9.963757	.88	9.629606	5.83	0.370394	55
6	.593659	4.93	.963704	.90	.629956	5.83	.370044	54
7	.593955	4.93	.963650	.90	.630306	5.83	.369694	53
8	.594251	4.93	.963596	.90	.630656	5.82	.369344	52
9	.594547	4.92	.963542	.90	.631005	5.83	.368995	51
10	9.594842	4.92	9.963488	.90	9.631355	5.82	0.368645	50
11	.595137	4.92	.963434	.92	.631704	5.82	.368296	49
12	.595432	4.92	.963379	.90	.632053	5.82	.367947	48
13	.595727	4.90	.963325	.90	.632402	5.80	.367598	47
14	.596021	4.90	.963271	.90	.632750	5.82	.367250	46
15	9.596315	4.90	9.963217	.90	9.633099	5.80	0.366901	45
16	.596609	4.90	.963163	.92	.633447	5.80	.366553	44
17	.596903	4.88	.963108	.90	.633795	5.80	.366205	43
18	.597196	4.90	.963054	.92	.634143	5.78	.365857	42
19	.597490	4.88	.962999	.90	.634490	5.80	.365510	41
20	9.597783	4.87	9.962945	.92	9.634838	5.78	0.365162	40
21	.598075	4.88	.962890	.90	.635185	5.78	.364815	39
22	.598368	4.87	.962836	.92	.635532	5.78	.364468	38
23	.598660	4.87	.962781	.90	.635879	5.78	.364121	37
24	.598952	4.87	.962727	.92	.636226	5.77	.363774	36
25	9.599244	4.87	9.962672	.92	9.636572	5.78	0.363428	35
26	.599536	4.85	.962617	.92	.636919	5.77	.363081	34
27	.599827	4.85	.962562	.90	.637265	5.77	.362735	33
28	.600118	4.85	.962508	.92	.637611	5.75	.362389	32
29	.600409	4.85	.962453	.92	.637956	5.77	.362044	31
30	9.600700	4.83	9.962398	.92	9.638302	5.75	0.361698	30
31	.600990	4.83	.962343	.92	.638647	5.75	.361353	29
32	.601280	4.83	.962288	.92	.638992	5.75	.361008	28
33	.601570	4.83	.962233	.92	.639337	5.75	.360663	27
34	.601860	4.83	.962178	.92	.639682	5.75	.360318	26
35	9.602150	4.82	9.962123	.93	9.640027	5.73	0.359973	25
36	.602439	4.82	.962067	.92	.640371	5.75	.359629	24
37	.602728	4.82	.962012	.92	.640716	5.73	.359284	23
38	.603017	4.80	.961957	.92	.641060	5.73	.358940	22
39	.603305	4.82	.961902	.93	.641404	5.72	.358596	21
40	9.603594	4.80	9.961846	.92	9.641747	5.73	0.358253	20
41	.603882	4.80	.961791	.93	.642091	5.72	.357909	19
42	.604170	4.78	.961735	.92	.642434	5.72	.357566	18
43	.604457	4.80	.961680	.93	.642777	5.72	.357223	17
44	.604745	4.78	.961624	.92	.643120	5.72	.356880	16
45	9.605032	4.78	9.961569	.93	9.643463	5.72	0.356537	15
46	.605319	4.78	.961513	.92	.643806	5.70	.356194	14
47	.605606	4.77	.961458	.93	.644148	5.70	.355852	13
48	.605892	4.78	.961402	.93	.644490	5.70	.355510	12
49	.606179	4.77	.961346	.93	.644832	5.70	.355168	11
50	9.606465	4.77	9.961290	.92	9.645174	5.70	0.354826	10
51	.606751	4.75	.961235	.93	.645516	5.68	.354484	9
52	.607036	4.77	.961179	.93	.645857	5.70	.354143	8
53	.607322	4.75	.961123	.93	.646199	5.68	.353801	7
54	.607607	4.75	.961067	.93	.646540	5.68	.353460	6
55	9.607892	4.75	9.961011	.93	9.646881	5.68	0.353119	5
56	.608177	4.73	.960955	.93	.647222	5.67	.352778	4
57	.608461	4.73	.960899	.93	.647562	5.68	.352438	3
58	.608745	4.73	.960843	.95	.647903	5.67	.352097	2
59	.609029	4.73	.960786	.93	.648243	5.67	.351757	1
60	9.609313		9.960730		9.648583		0.351417	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.609313	4.73	9.960730	.93	9.648583	5.67	0.351417	60
1	.609597	4.72	.960674	.93	.648923	5.67	.351077	59
2	.609880	4.73	.960618	.95	.649263	5.65	.350737	58
3	.610164	4.72	.960561	.93	.649602	5.67	.350398	57
4	.610447	4.70	.960505	.95	.649942	5.65	.350058	56
5	9.610729	4.72	9.960448	.93	9.650281	5.65	0.349719	55
6	.611012	4.70	.960392	.95	.650620	5.65	.349380	54
7	.611294	4.70	.960335	.93	.650959	5.63	.349041	53
8	.611576	4.70	.960279	.95	.651297	5.65	.348703	52
9	.611858	4.70	.960222	.95	.651636	5.63	.348364	51
10	9.612140	4.68	9.960165	.93	9.651974	5.63	0.348026	50
11	.612421	4.68	.960109	.95	.652312	5.63	.347688	49
12	.612702	4.68	.960052	.95	.652650	5.63	.347350	48
13	.612983	4.68	.959995	.95	.652988	5.63	.347012	47
14	.613264	4.68	.959938	.93	.653326	5.62	.346674	46
15	9.613545	4.67	9.959882	.95	9.653663	5.62	0.346337	45
16	.613825	4.67	.959825	.95	.654000	5.62	.346000	44
17	.614105	4.67	.959768	.95	.654337	5.62	.345663	43
18	.614385	4.67	.959711	.95	.654674	5.62	.345326	42
19	.614665	4.65	.959654	.97	.655011	5.62	.344989	41
20	9.614944	4.65	9.959596	.95	9.655348	5.60	0.344652	40
21	.615223	4.65	.959539	.95	.655684	5.60	.344316	39
22	.615502	4.65	.959482	.95	.656020	5.60	.343980	38
23	.615781	4.65	.959425	.95	.656356	5.60	.343644	37
24	.616060	4.63	.959368	.97	.656692	5.60	.343308	36
25	9.616338	4.63	9.959310	.95	9.657028	5.60	0.342972	35
26	.616616	4.63	.959253	.97	.657364	5.58	.342636	34
27	.616894	4.63	.959195	.95	.657699	5.58	.342301	33
28	.617172	4.63	.959138	.97	.658034	5.58	.341966	32
29	.617450	4.62	.959080	.95	.658369	5.58	.341631	31
30	9.617727	4.62	9.959023	.97	9.658704	5.58	0.341296	30
31	.618004	4.62	.958965	.95	.659039	5.57	.340961	29
32	.618281	4.62	.958908	.97	.659373	5.58	.340627	28
33	.618558	4.60	.958850	.97	.659708	5.57	.340292	27
34	.618834	4.60	.958792	.97	.660042	5.57	.339958	26
35	9.619110	4.60	9.958734	.95	9.660376	5.57	0.339624	25
36	.619386	4.60	.958677	.97	.660710	5.55	.339290	24
37	.619662	4.60	.958619	.97	.661043	5.57	.338957	23
38	.619938	4.58	.958561	.97	.661377	5.55	.338623	22
39	.620213	4.58	.958503	.97	.661710	5.55	.338290	21
40	9.620488	4.58	9.958445	.97	9.662043	5.55	0.337957	20
41	.620763	4.58	.958387	.97	.662376	5.55	.337624	19
42	.621038	4.58	.958329	.97	.662709	5.55	.337291	18
43	.621313	4.57	.958271	.97	.663042	5.55	.336958	17
44	.621587	4.57	.958213	.98	.663375	5.53	.336625	16
45	9.621861	4.57	9.958154	.97	9.663707	5.53	0.336293	15
46	.622135	4.57	.958096	.97	.664039	5.53	.335961	14
47	.622409	4.55	.958038	.98	.664371	5.53	.335629	13
48	.622682	4.57	.957979	.97	.664703	5.53	.335297	12
49	.622956	4.55	.957921	.97	.665035	5.52	.334965	11
50	9.623229	4.55	9.957863	.98	9.665366	5.53	0.334634	10
51	.623502	4.53	.957804	.97	.665698	5.52	.334302	9
52	.623774	4.55	.957746	.98	.666029	5.52	.333971	8
53	.624047	4.53	.957687	.98	.666360	5.52	.333640	7
54	.624319	4.53	.957628	.97	.666691	5.50	.333309	6
55	9.624591	4.53	9.957570	.98	9.667021	5.52	0.332979	5
56	.624863	4.53	.957511	.98	.667352	5.50	.332648	4
57	.625135	4.52	.957452	.98	.667682	5.52	.332318	3
58	.625406	4.52	.957393	.97	.668013	5.50	.331987	2
59	.625677	4.52	.957335	.98	.668343	5.50	.331657	1
60	9.625948		9.957276		9.668673		0.331327	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.625948	4.52	9.957276	.98	9.668673	5.48	0.331327	60
1	.626219	4.52	.957217	.98	.669002	5.50	.330998	59
2	.626490	4.50	.957158	.98	.669332	5.48	.330668	58
3	.626760	4.50	.957099	.98	.669661	5.50	.330339	57
4	.627030	4.50	.957040	.98	.669991	5.48	.330009	56
5	9.627300	4.50	9.956981	1.00	9.670320	5.48	0.329680	55
6	.627570	4.50	.956921	.98	.670649	5.47	.329351	54
7	.627840	4.48	.956862	.98	.670977	5.48	.329023	53
8	.628109	4.48	.956803	.98	.671306	5.48	.328694	52
9	.628378	4.48	.956744	1.00	.671635	5.47	.328365	51
10	9.628647	4.48	9.956684	.98	9.671963	5.47	0.328037	50
11	.628916	4.48	.956625	.98	.672291	5.47	.327709	49
12	.629185	4.47	.956566	1.00	.672619	5.47	.327381	48
13	.629453	4.47	.956506	.98	.672947	5.45	.327053	47
14	.629721	4.47	.956447	1.00	.673274	5.47	.326726	46
15	9.629989	4.47	9.956387	1.00	9.673602	5.45	0.326398	45
16	.630257	4.45	.956327	.98	.673929	5.47	.326071	44
17	.630524	4.47	.956268	1.00	.674257	5.45	.325743	43
18	.630792	4.45	.956208	1.00	.674584	5.45	.325416	42
19	.631059	4.45	.956148	.98	.674911	5.43	.325089	41
20	9.631326	4.45	9.956089	1.00	9.675237	5.45	0.324763	40
21	.631593	4.43	.956029	1.00	.675564	5.43	.324436	39
22	.631859	4.43	.955969	1.00	.675890	5.45	.324110	38
23	.632125	4.45	.955909	1.00	.676217	5.43	.323783	37
24	.632392	4.43	.955849	1.00	.676543	5.43	.323457	36
25	9.632658	4.42	9.955789	1.00	9.676869	5.42	0.323131	35
26	.632923	4.43	.955729	1.00	.677194	5.43	.322806	34
27	.633189	4.42	.955669	1.00	.677520	5.43	.322480	33
28	.633454	4.42	.955609	1.02	.677846	5.42	.322154	32
29	.633719	4.42	.955548	1.00	.678171	5.42	.321829	31
30	9.633984	4.42	9.955488	1.00	9.678496	5.42	0.321504	30
31	.634249	4.42	.955428	1.00	.678821	5.42	.321179	29
32	.634514	4.40	.955368	1.02	.679146	5.42	.320854	28
33	.634778	4.40	.955307	1.00	.679471	5.40	.320529	27
34	.635042	4.40	.955247	1.02	.679795	5.42	.320205	26
35	9.635306	4.40	9.955186	1.00	9.680120	5.40	0.319880	25
36	.635570	4.40	.955126	1.02	.680444	5.40	.319556	24
37	.635834	4.38	.955065	1.00	.680768	5.40	.319232	23
38	.636097	4.38	.955005	1.02	.681092	5.40	.318908	22
39	.636360	4.38	.954944	1.02	.681416	5.40	.318584	21
40	9.636623	4.38	9.954883	1.00	9.681740	5.38	0.318260	20
41	.636886	4.37	.954823	1.02	.682063	5.40	.317937	19
42	.637148	4.38	.954762	1.02	.682387	5.38	.317613	18
43	.637411	4.37	.954701	1.02	.682710	5.38	.317290	17
44	.637673	4.37	.954640	1.02	.683033	5.38	.316967	16
45	9.637935	4.37	9.954579	1.02	9.683356	5.38	0.316644	15
46	.638197	4.35	.954518	1.02	.683679	5.37	.316321	14
47	.638458	4.37	.954457	1.02	.684001	5.38	.315999	13
48	.638720	4.35	.954396	1.02	.684324	5.37	.315676	12
49	.638981	4.35	.954335	1.02	.684646	5.37	.315354	11
50	9.639242	4.35	9.954274	1.02	9.684968	5.37	0.315032	10
51	.639503	4.35	.954213	1.02	.685290	5.37	.314710	9
52	.639764	4.33	.954152	1.03	.685612	5.37	.314388	8
53	.640024	4.33	.954090	1.02	.685934	5.35	.314066	7
54	.640284	4.33	.954029	1.02	.686255	5.37	.313745	6
55	9.640544	4.33	9.953968	1.03	9.686577	5.35	0.313423	5
56	.640804	4.33	.953906	1.02	.686898	5.35	.313102	4
57	.641064	4.33	.953845	1.03	.687219	5.35	.312781	3
58	.641324	4.32	.953783	1.02	.687540	5.35	.312460	2
59	.641583	4.32	.953722	1.03	.687861	5.35	.312139	1
60	9.641842		9.953660		9.688182		0.311818	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.641842	4.32	9.953660	1.02	9.688182	5.33	0.311818	60
1	.642101	4.32	.953599	1.03	.688502	5.35	.311498	59
2	.642360	4.30	.953537	1.03	.688823	5.33	.311177	58
3	.642618	4.32	.953475	1.03	.689143	5.33	.310857	57
4	.642877	4.30	.953413	1.02	.689463	5.33	.310537	56
5	9.643135	4.30	9.953352	1.03	9.689783	5.33	0.310217	55
6	.643393	4.28	.953290	1.03	.690103	5.33	.309897	54
7	.643650	4.30	.953228	1.03	.690423	5.32	.309577	53
8	.643908	4.28	.953166	1.03	.690742	5.33	.309258	52
9	.644165	4.30	.953104	1.03	.691062	5.32	.308938	51
10	9.644423	4.28	9.953042	1.03	9.691381	5.32	0.308619	50
11	.644680	4.27	.952980	1.03	.691700	5.32	.308300	49
12	.644936	4.28	.952918	1.05	.692019	5.32	.307981	48
13	.645193	4.28	.952855	1.03	.692338	5.30	.307662	47
14	.645450	4.27	.952793	1.03	.692656	5.32	.307344	46
15	9.645706	4.27	9.952731	1.03	9.692975	5.30	0.307025	45
16	.645962	4.27	.952669	1.05	.693293	5.32	.306707	44
17	.646218	4.27	.952606	1.03	.693612	5.30	.306388	43
18	.646474	4.25	.952544	1.05	.693930	5.30	.306070	42
19	.646729	4.25	.952481	1.03	.694248	5.30	.305752	41
20	9.646984	4.27	9.952419	1.05	9.694566	5.28	0.305434	40
21	.647240	4.23	.952356	1.03	.694883	5.30	.305117	39
22	.647494	4.25	.952294	1.05	.695201	5.28	.304799	38
23	.647749	4.25	.952231	1.05	.695518	5.30	.304482	37
24	.648004	4.23	.952168	1.03	.695836	5.28	.304164	36
25	9.648258	4.23	9.952106	1.05	9.696153	5.28	0.303847	35
26	.648512	4.23	.952043	1.05	.696470	5.28	.303530	34
27	.648766	4.23	.951980	1.05	.696787	5.27	.303213	33
28	.649020	4.23	.951917	1.05	.697103	5.28	.302897	32
29	.649274	4.22	.951854	1.05	.697420	5.27	.302580	31
30	9.649527	4.23	9.951791	1.05	9.697736	5.28	0.302264	30
31	.649781	4.22	.951728	1.05	.698053	5.27	.301947	29
32	.650034	4.22	.951665	1.05	.698369	5.27	.301631	28
33	.650287	4.20	.951602	1.05	.698685	5.27	.301315	27
34	.650539	4.22	.951539	1.05	.699001	5.25	.300999	26
35	9.650792	4.20	9.951476	1.07	9.699316	5.27	0.300684	25
36	.651044	4.22	.951412	1.05	.699632	5.25	.300368	24
37	.651297	4.20	.951349	1.05	.699947	5.27	.300053	23
38	.651549	4.18	.951286	1.07	.700263	5.25	.299737	22
39	.651800	4.20	.951222	1.05	.700578	5.25	.299422	21
40	9.652052	4.20	9.951159	1.05	9.700893	5.25	0.299107	20
41	.652304	4.18	.951096	1.07	.701208	5.25	.298792	19
42	.652555	4.18	.951032	1.07	.701523	5.23	.298477	18
43	.652806	4.18	.950968	1.05	.701837	5.25	.298163	17
44	.653057	4.18	.950905	1.07	.702152	5.23	.297848	16
45	9.653308	4.17	9.950841	1.05	9.702466	5.25	0.297534	15
46	.653558	4.17	.950778	1.07	.702781	5.23	.297219	14
47	.653808	4.18	.950714	1.07	.703095	5.23	.296905	13
48	.654059	4.17	.950650	1.07	.703409	5.22	.296591	12
49	.654309	4.15	.950586	1.07	.703722	5.23	.296278	11
50	9.654558	4.17	9.950522	1.07	9.704036	5.23	0.295964	10
51	.654808	4.17	.950458	1.07	.704350	5.22	.295650	9
52	.655058	4.15	.950394	1.07	.704663	5.22	.295337	8
53	.655307	4.15	.950330	1.07	.704976	5.23	.295024	7
54	.655556	4.15	.950 6	1.07	.705290	5.22	.294710	6
55	9.655805	4.15	9.950202	1.07	9.705603	5.22	0.294397	5
56	.656054	4.13	.950138	1.07	.705916	5.20	.294084	4
57	.656302	4.15	.950074	1.07	.706228	5.22	.293772	3
58	.656551	4.13	.950010	1.08	.706541	5.22	.293459	2
59	.656799	4.13	.949945	1.07	.706854	5.20	.293146	1
60	9.657047		9.949881		9.707166		0.292834	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.657047	4.13	9.949881	1.08	9.707166	5.20	0.292834	60
1	.657295	4.12	.949816	1.07	.707478	5.20	.292522	59
2	.657542	4.13	.949752	1.07	.707790	5.20	.292210	58
3	.657790	4.12	.949688	1.08	.708102	5.20	.291898	57
4	.658037	4.12	.949623	1.08	.708414	5.20	.291586	56
5	9.658284	4.12	9.949558	1.07	9.708726	5.18	0.291274	55
6	.658531	4.12	.949494	1.08	.709037	5.20	.290963	54
7	.658778	4.12	.949429	1.08	.709349	5.18	.290651	53
8	.659025	4.10	.949364	1.07	.709660	5.18	.290340	52
9	.659271	4.10	.949300	1.08	.709971	5.18	.290029	51
10	9.659517	4.10	9.949235	1.08	9.710282	5.18	0.289718	50
11	.659763	4.10	.949170	1.08	.710593	5.18	.289407	49
12	.660009	4.10	.949105	1.08	.710904	5.18	.289096	48
13	.660255	4.10	.949040	1.08	.711215	5.17	.288785	47
14	.660501	4.08	.948975	1.08	.711525	5.18	.288475	46
15	9.660746	4.08	9.948910	1.08	9.711836	5.17	0.288164	45
16	.660991	4.08	.948845	1.08	.712146	5.17	.287854	44
17	.661236	4.08	.948780	1.08	.712456	5.17	.287544	43
18	.661481	4.08	.948715	1.08	.712766	5.17	.287234	42
19	.661726	4.07	.948650	1.10	.713076	5.17	.286924	41
20	9.661970	4.07	9.948584	1.08	9.713386	5.17	0.286614	40
21	.662214	4.08	.948519	1.08	.713696	5.15	.286304	39
22	.662459	4.07	.948454	1.10	.714005	5.15	.285995	38
23	.662703	4.05	.948388	1.08	.714314	5.17	.285686	37
24	.662946	4.07	.948323	1.10	.714624	5.15	.285376	36
25	9.663190	4.05	9.948257	1.08	9.714933	5.15	0.285067	35
26	.663433	4.07	.948192	1.10	.715242	5.15	.284758	34
27	.663677	4.05	.948126	1.10	.715551	5.15	.284449	33
28	.663920	4.05	.948060	1.08	.715860	5.13	.284140	32
29	.664163	4.05	.947995	1.10	.716168	5.15	.283832	31
30	9.664406	4.03	9.947929	1.10	9.716477	5.13	0.283523	30
31	.664648	4.05	.947863	1.10	.716785	5.13	.283215	29
32	.664891	4.03	.947797	1.10	.717093	5.13	.282907	28
33	.665133	4.03	.947731	1.10	.717401	5.13	.282599	27
34	.665375	4.03	.947665	1.08	.717709	5.13	.282291	26
35	9.665617	4.03	9.947600	1.12	9.718017	5.13	0.281983	25
36	.665859	4.02	.947533	1.10	.718325	5.13	.281675	24
37	.666100	4.03	.947467	1.10	.718633	5.12	.281367	23
38	.666342	4.02	.947401	1.10	.718940	5.13	.281060	22
39	.666583	4.02	.947335	1.10	.719248	5.12	.280752	21
40	9.666824	4.02	9.947269	1.10	9.719555	5.12	0.280445	20
41	.667065	4.00	.947203	1.12	.719862	5.12	.280138	19
42	.667305	4.02	.947136	1.10	.720169	5.12	.279831	18
43	.667546	4.00	.947070	1.10	.720476	5.12	.279524	17
44	.667786	4.02	.947004	1.12	.720783	5.10	.279217	16
45	9.668027	4.00	9.946937	1.10	9.721089	5.12	0.278911	15
46	.668267	3.98	.946871	1.12	.721396	5.10	.278604	14
47	.668506	4.00	.946804	1.10	.721702	5.12	.278298	13
48	.668746	4.00	.946738	1.12	.722009	5.10	.277991	12
49	.668986	3.98	.946671	1.12	.722315	5.10	.277685	11
50	9.669225	3.98	9.946604	1.10	9.722621	5.10	0.277379	10
51	.669464	3.98	.946538	1.12	.722927	5.08	.277073	9
52	.669703	3.98	.946471	1.12	.723232	5.10	.276768	8
53	.669942	3.98	.946404	1.12	.723538	5.10	.276462	7
54	.670181	3.97	.946337	1.12	.723844	5.08	.276156	6
55	9.670419	3.98	9.946270	1.12	9.724149	5.08	0.275851	5
56	.670658	3.97	.946203	1.12	.724454	5.10	.275546	4
57	.670896	3.97	.946136	1.12	.724760	5.08	.275240	3
58	.671134	3.97	.946069	1.12	.725065	5.08	.274935	2
59	.671372	3.95	.946002	1.12	.725370	5.07	.274630	1
60	9.671609		9.945935		9.725674		0.274326	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.671609	3.97	9.945935	1.12	9.725674	5.08	0.274326	60
1	.671847	3.95	.945868	1.13	.725979	5.08	.274021	59
2	.672084	3.95	.945800	1.12	.726284	5.07	.273716	58
3	.672321	3.95	.945733	1.12	.726588	5.07	.273412	57
4	.672558	3.95	.945666	1.13	.726892	5.08	.273108	56
5	9.672795	3.95	9.945598	1.12	9.727197	5.07	0.272803	55
6	.673032	3.93	.945531	1.12	.727501	5.07	.272499	54
7	.673268	3.95	.945464	1.13	.727805	5.07	.272195	53
8	.673505	3.93	.945396	1.13	.728109	5.05	.271891	52
9	.673741	3.93	.945328	1.12	.728412	5.07	.271588	51
10	9.673977	3.93	9.945261	1.13	9.728716	5.07	0.271284	50
11	.674213	3.92	.945193	1.13	.729020	5.05	.270980	49
12	.674448	3.93	.945125	1.12	.729323	5.05	.270677	48
13	.674684	3.92	.945058	1.13	.729626	5.05	.270374	47
14	.674919	3.93	.944990	1.13	.729929	5.07	.270071	46
15	9.675155	3.92	9.944922	1.13	9.730233	5.03	0.269767	45
16	.675390	3.90	.944854	1.13	.730535	5.05	.269465	44
17	.675624	3.92	.944786	1.13	.730838	5.05	.269162	43
18	.675859	3.92	.944718	1.13	.731141	5.05	.268859	42
19	.676094	3.90	.944650	1.13	.731444	5.03	.268556	41
20	9.676328	3.90	9.944582	1.13	9.731746	5.03	0.268254	40
21	.676562	3.90	.944514	1.13	.732048	5.05	.267952	39
22	.676796	3.90	.944446	1.15	.732351	5.03	.267649	38
23	.677030	3.90	.944377	1.13	.732653	5.03	.267347	37
24	.677264	3.90	.944309	1.13	.732955	5.03	.267045	36
25	9.677498	3.88	9.944241	1.15	9.733257	5.02	0.266743	35
26	.677731	3.88	.944172	1.13	.733558	5.03	.266442	34
27	.677964	3.88	.944104	1.13	.733860	5.03	.266140	33
28	.678197	3.88	.944036	1.15	.734162	5.02	.265838	32
29	.678430	3.88	.943967	1.13	.734463	5.02	.265537	31
30	9.678663	3.87	9.943899	1.15	9.734764	5.03	0.265236	30
31	.678895	3.88	.943830	1.15	.735066	5.02	.264934	29
32	.679128	3.87	.943761	1.13	.735367	5.02	.264633	28
33	.679360	3.87	.943693	1.15	.735668	5.02	.264332	27
34	.679592	3.87	.943624	1.15	.735969	5.00	.264031	26
35	9.679824	3.87	9.943555	1.15	9.736269	5.02	0.263731	25
36	.680056	3.87	.943486	1.15	.736570	5.00	.263430	24
37	.680288	3.85	.943417	1.15	.736870	5.02	.263130	23
38	.680519	3.85	.943348	1.15	.737171	5.00	.262829	22
39	.680750	3.87	.943279	1.15	.737471	5.00	.262529	21
40	9.680982	3.85	9.943210	1.15	9.737771	5.00	0.262229	20
41	.681213	3.83	.943141	1.15	.738071	5.00	.261929	19
42	.681443	3.85	.943072	1.15	.738371	5.00	.261629	18
43	.681674	3.85	.943003	1.15	.738671	5.00	.261329	17
44	.681905	3.83	.942934	1.17	.738971	5.00	.261029	16
45	9.682135	3.83	9.942864	1.15	9.739271	4.98	0.260729	15
46	.682365	3.83	.942795	1.15	.739570	5.00	.260430	14
47	.682595	3.83	.942726	1.17	.739870	4.98	.260130	13
48	.682825	3.83	.942656	1.15	.740169	4.98	.259831	12
49	.683055	3.82	.942587	1.17	.740468	4.98	.259532	11
50	9.683284	3.83	9.942517	1.15	9.740767	4.98	0.259233	10
51	.683514	3.82	.942448	1.17	.741066	4.98	.258934	9
52	.683743	3.82	.942378	1.17	.741365	4.98	.258635	8
53	.683972	3.82	.942308	1.15	.741664	4.97	.258336	7
54	.684201	3.82	.942239	1.17	.741962	4.98	.258038	6
55	9.684430	3.80	9.942169	1.17	9.742261	4.97	0.257739	5
56	.684658	3.82	.942099	1.17	.742559	4.98	.257441	4
57	.684887	3.80	.942029	1.17	.742858	4.97	.257142	3
58	.685115	3.80	.941959	1.17	.743156	4.97	.256844	2
59	.685343	3.80	.941889	1.17	.743454	4.97	.256546	1
60	9.685571		9.941819		9.743752		0.256248	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.685571	3.80	9.941819	1.17	9.743752	4.97	0.256248	60
1	.685799	3.80	.941749	1.17	.744050	4.97	.255950	59
2	.686027	3.78	.941679	1.17	.744348	4.95	.255652	58
3	.686254	3.80	.941609	1.17	.744645	4.97	.255355	57
4	.686482	3.78	.941539	1.17	.744943	4.95	.255057	56
5	9.686709	3.78	9.941469	1.18	9.745240	4.97	0.254760	55
6	.686936	3.78	.941398	1.17	.745538	4.95	.254462	54
7	.687163	3.77	.941328	1.17	.745835	4.95	.254165	53
8	.687389	3.78	.941258	1.18	.746132	4.95	.253868	52
9	.687616	3.78	.941187	1.17	.746429	4.95	.253571	51
10	9.687843	3.77	9.941117	1.18	9.746726	4.95	0.253274	50
11	.688069	3.77	.941046	1.18	.747023	4.93	.252977	49
12	.688295	3.77	.940975	1.17	.747319	4.95	.252681	48
13	.688521	3.77	.940905	1.18	.747616	4.95	.252384	47
14	.688747	3.75	.940834	1.18	.747913	4.93	.252087	46
15	9.688972	3.77	9.940763	1.17	9.748209	4.93	0.251791	45
16	.689198	3.75	.940693	1.18	.748505	4.93	.251495	44
17	.689423	3.75	.940622	1.18	.748801	4.93	.251199	43
18	.689648	3.75	.940551	1.18	.749097	4.93	.250903	42
19	.689873	3.75	.940480	1.18	.749393	4.93	.250607	41
20	9.690098	3.75	9.940409	1.18	9.749689	4.93	0.250311	40
21	.690323	3.75	.940338	1.18	.749985	4.93	.250015	39
22	.690548	3.73	.940267	1.18	.750281	4.92	.249719	38
23	.690772	3.73	.940196	1.18	.750576	4.93	.249424	37
24	.690996	3.73	.940125	1.18	.750872	4.92	.249128	36
25	9.691220	3.73	9.940054	1.20	9.751167	4.92	0.248833	35
26	.691444	3.73	.939982	1.18	.751462	4.92	.248538	34
27	.691668	3.73	.939911	1.18	.751757	4.92	.248243	33
28	.691892	3.72	.939840	1.20	.752052	4.92	.247948	32
29	.692115	3.73	.939768	1.18	.752347	4.92	.247653	31
30	9.692339	3.72	9.939697	1.20	9.752642	4.92	0.247358	30
31	.692562	3.72	.939625	1.18	.752937	4.90	.247063	29
32	.692785	3.72	.939554	1.20	.753231	4.92	.246769	28
33	.693008	3.72	.939482	1.20	.753526	4.90	.246474	27
34	.693231	3.70	.939410	1.18	.753820	4.92	.246180	26
35	9.693453	3.72	9.939339	1.20	9.754115	4.90	0.245885	25
36	.693676	3.70	.939267	1.20	.754409	4.90	.245591	24
37	.693898	3.70	.939195	1.20	.754703	4.90	.245297	23
38	.694120	3.70	.939123	1.18	.754997	4.90	.245003	22
39	.694342	3.70	.939052	1.20	.755291	4.90	.244709	21
40	9 694564	3.70	9.938980	1.20	9.755585	4.88	0.244415	20
41	.694786	3.68	.938908	1.20	.755878	4.90	.244122	19
42	.695007	3.70	.938836	1.22	.756172	4.88	.243828	18
43	.695229	3.68	.938763	1.20	.756465	4.90	.243535	17
44	.695450	3.68	.938691	1.20	.756759	4.88	.243241	16
45	9.695671	3.68	9.938619	1.20	9.757052	4.88	0.242948	15
46	.695892	3.68	.938547	1.20	.757345	4.88	.242655	14
47	.696113	3.68	.938475	1.22	.757638	4.88	.242362	13
48	.696334	3.67	.938402	1.20	.757931	4.88	.242069	12
49	.696554	3.68	.938330	1.20	.758224	4.88	.241776	11
50	9.696775	3.67	9.938258	1.22	9.758517	4.88	0.241483	10
51	.696995	3.67	.938185	1.20	.758810	4.87	.241190	9
52	.697215	3.67	.938113	1.22	.759102	4.88	.240898	8
53	.697435	3.65	.938040	1.22	.759395	4.87	.240605	7
54	.697654	3.67	.937967	1.20	.759687	4.87	.240313	6
55	9.697874	3.67	9.937895	1.22	9.759979	4.88	0.240021	5
56	.698094	3.65	.937822	1.22	.760272	4.87	.239728	4
57	.698313	3.65	.937749	1.22	.760564	4.87	.239436	3
58	.698532	3.65	.937676	1.20	.760856	4.87	.239144	2
59	.698751	3.65	.937604	1.22	.761148	4.85	.238852	1
60	9.698970		9.937531		9.761439		0.238561	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.698970	3.65	9.937531	1.22	9.761439	4.87	0.238561	60
1	.699189	3.63	.937458	1.22	.761731	4.87	.238269	59
2	.699407	3.65	.937385	1.22	.762023	4.85	.237977	58
3	.699626	3.63	.937312	1.23	.762314	4.87	.237686	57
4	.699844	3.63	.937238	1.22	.762606	4.85	.237394	56
5	9.700062	3.63	9.937165	1.22	9.762897	4.85	0.237103	55
6	.700280	3.63	.937092	1.22	.763188	4.85	.236812	54
7	.700498	3.63	.937019	1.22	.763479	4.85	.236521	53
8	.700716	3.62	.936946	1.23	.763770	4.85	.236230	52
9	.700933	3.63	.936872	1.22	.764061	4.85	.235939	51
10	9.701151	3.62	9.936799	1.23	9.764352	4.85	0.235648	50
11	.701368	3.62	.936725	1.22	.764643	4.83	.235357	49
12	.701585	3.62	.936652	1.23	.764933	4.85	.235067	48
13	.701802	3.62	.936578	1.22	.765224	4.83	.234776	47
14	.702019	3.62	.936505	1.23	.765514	4.85	.234486	46
15	9.702236	3.60	9.936431	1.23	9.765805	4.83	0.234195	45
16	.702452	3.62	.936357	1.22	.766095	4.83	.233905	44
17	.702669	3.60	.936284	1.23	.766385	4.83	.233615	43
18	.702885	3.60	.936210	1.23	.766675	4.83	.233325	42
19	.703101	3.60	.936136	1.23	.766965	4.83	.233035	41
20	9.703317	3.60	9.936062	1.23	9.767255	4.83	0.232745	40
21	.703533	3.60	.935988	1.23	.767545	4.82	.232455	39
22	.703749	3.58	.935914	1.23	.767834	4.83	.232166	38
23	.703964	3.58	.935840	1.23	.768124	4.83	.231876	37
24	.704179	3.60	.935766	1.23	.768414	4.82	.231586	36
25	9.704395	3.58	9.935692	1.23	9.768703	4.82	0.231297	35
26	.704610	3.58	.935618	1.25	.768992	4.82	.231008	34
27	.704825	3.58	.935543	1.23	.769281	4.83	.230719	33
28	.705040	3.57	.935469	1.23	.769571	4.82	.230429	32
29	.705254	3.58	.935395	1.25	.769860	4.80	.230140	31
30	9.705469	3.57	9.935320	1.23	9.770148	4.82	0.229852	30
31	.705683	3.58	.935246	1.25	.770437	4.82	.229563	29
32	.705898	3.57	.935171	1.23	.770726	4.82	.229274	28
33	.706112	3.57	.935097	1.25	.771015	4.80	.228985	27
34	.706326	3.55	.935022	1.23	.771303	4.82	.228697	26
35	9.706539	3.57	9.934948	1.25	9.771592	4.80	0.228408	25
36	.706753	3.57	.934873	1.25	.771880	4.80	.228120	24
37	.706967	3.55	.934798	1.25	.772168	4.82	.227832	23
38	.707180	3.55	.934723	1.23	.772457	4.80	.227543	22
39	.707393	3.55	.934649	1.25	.772745	4.80	.227255	21
40	9.707606	3.55	9.934574	1.25	9.773033	4.80	0.226967	20
41	.707819	3.55	.934499	1.25	.773321	4.78	.226679	19
42	.708032	3.55	.934424	1.25	.773608	4.80	.226392	18
43	.708245	3.55	.934349	1.25	.773896	4.80	.226104	17
44	.708458	3.53	.934274	1.25	.774184	4.78	.225816	16
45	9.708670	3.53	9.934199	1.27	9.774471	4.80	0.225529	15
46	.708882	3.53	.934123	1.25	.774759	4.78	.225241	14
47	.709094	3.53	.934048	1.25	.775046	4.78	.224954	13
48	.709306	3.53	.933973	1.25	.775333	4.80	.224667	12
49	.709518	3.53	.933898	1.27	.775621	4.78	.224379	11
50	9.709730	3.52	9.933822	1.25	9.775908	4.78	0.224092	10
51	.709941	3.53	.933747	1.27	.776195	4.78	.223805	9
52	.710153	3.52	.933671	1.25	.776482	4.77	.223518	8
53	.710364	3.52	.933596	1.27	.776768	4.78	.223232	7
54	.710575	3.52	.933520	1.25	.777055	4.78	.222945	6
55	9.710786	3.52	9.933445	1.27	9.777342	4.77	0.222658	5
56	.710997	3.52	.933369	1.27	.777628	4.78	.222372	4
57	.711208	3.52	.933293	1.27	.777915	4.77	.222085	3
58	.711419	3.50	.933217	1.27	.778201	4.78	.221799	2
59	.711629	3.50	.933141	1.25	.778488	4.77	.221512	1
60	9.711839		9.933066		9.778774		0.221226	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.711839	3.52	9.933066	1.27	9.778774	4.77	0.221226	60
1	.712050	3.50	.932990	1.27	.779060	4.77	.220940	59
2	.712260	3.48	.932914	1.27	.779346	4.77	.220654	58
3	.712469	3.50	.932838	1.27	.779632	4.77	.220368	57
4	.712679	3.50	.932762	1.28	.779918	4.75	.220082	56
5	9.712889	3.48	9.932685	1.27	9.780203	4.77	0.219797	55
6	.713098	3.50	.932609	1.27	.780489	4.77	.219511	54
7	.713308	3.48	.932533	1.27	.780775	4.75	.219225	53
8	.713517	3.48	.932457	1.28	.781060	4.77	.218940	52
9	.713726	3.48	.932380	1.27	.781346	4.75	.218654	51
10	9.713935	3.48	9.932304	1.27	9.781631	4.75	0.218369	50
11	.714144	3.47	.932228	1.28	.781916	4.75	.218084	49
12	.714352	3.48	.932151	1.27	.782201	4.75	.217799	48
13	.714561	3.47	.932075	1.28	.782486	4.75	.217514	47
14	.714769	3.48	.931998	1.28	.782771	4.75	.217229	46
15	9.714978	3.47	9.931921	1.27	9.783056	4.75	0.216944	45
16	.715186	3.47	.931845	1.28	.783341	4.75	.216659	44
17	.715394	3.47	.931768	1.28	.783626	4.73	.216374	43
18	.715602	3.45	.931691	1.28	.783910	4.75	.216090	42
19	.715809	3.47	.931614	1.28	.784195	4.73	.215805	41
20	9.716017	3.45	9.931537	1.28	9.784479	4.75	0.215521	40
21	.716224	3.47	.931460	1.28	.784764	4.73	.215236	39
22	.716432	3.45	.931383	1.28	.785048	4.73	.214952	38
23	.716639	3.45	.931306	1.28	.785332	4.73	.214668	37
24	.716846	3.45	.931229	1.28	.785616	4.73	.214384	36
25	9.717053	3.43	9.931152	1.28	9.785900	4.73	0.214100	35
26	.717259	3.45	.931075	1.28	.786184	4.73	.213816	34
27	.717466	3.45	.930998	1.28	.786468	4.73	.213532	33
28	.717673	3.43	.930921	1.30	.786752	4.73	.213248	32
29	.717879	3.43	.930843	1.28	.787036	4.72	.212964	31
30	9.718085	3.43	9.930766	1.30	9.787319	4.73	0.212681	30
31	.718291	3.43	.930688	1.28	.787603	4.72	.212397	29
32	.718497	3.43	.930611	1.30	.787886	4.73	.212114	28
33	.718703	3.43	.930533	1.28	.788170	4.72	.211830	27
34	.718909	3.42	.930456	1.30	.788453	4.72	.211547	26
35	9.719114	3.43	9.930378	1.30	9.788736	4.72	0.211264	25
36	.719320	3.42	.930300	1.28	.789019	4.72	.210981	24
37	.719525	3.42	.930223	1.30	.789302	4.72	.210698	23
38	.719730	3.42	.930145	1.30	.789585	4.72	.210415	22
39	.719935	3.42	.930067	1.30	.789868	4.72	.210132	21
40	9.720140	3.42	9.929989	1.30	9.790151	4.72	0.209849	20
41	.720345	3.40	.929911	1.30	.790434	4.70	.209566	19
42	.720549	3.42	.929833	1.30	.790716	4.72	.209284	18
43	.720754	3.40	.929755	1.30	.790999	4.70	.209001	17
44	.720958	3.40	.929677	1.30	.791281	4.70	.208719	16
45	9.721162	3.40	9.929599	1.30	9.791563	4.72	0.208437	15
46	.721366	3.40	.929521	1.32	.791846	4.70	.208154	14
47	.721570	3.40	.929442	1.30	.792128	4.70	.207872	13
48	.721774	3.40	.929364	1.30	.792410	4.70	.207590	12
49	.721978	3.38	.929286	1.32	.792692	4.70	.207308	11
50	9.722181	3.40	9.929207	1.30	9.792974	4.70	0.207026	10
51	.722385	3.38	.929129	1.32	.793256	4.70	.206744	9
52	.722588	3.38	.929050	1.30	.793538	4.68	.206462	8
53	.722791	3.38	.928972	1.32	.793819	4.70	.206181	7
54	.722994	3.38	.928893	1.30	.794101	4.70	.205899	6
55	9.723197	3.38	9.928815	1.32	9.794383	4.68	0.205617	5
56	.723400	3.38	.928736	1.32	.794664	4.70	.205336	4
57	.723603	3.37	.928657	1.32	.794946	4.68	.205054	3
58	.723805	3.37	.928578	1.32	.795227	4.68	.204773	2
59	.724007	3.38	.928499	1.32	.795508	4.68	.204492	1
60	9.724210		9.928420		9.795789		0.204211	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.724210	3.37	9.928420	1.30	9.795789	4.68	0.204211	60
1	.724412	3.37	.928342	1.32	.796070	4.68	.203930	59
2	.724614	3.37	.928263	1.33	.796351	4.68	.203649	58
3	.724816	3.35	.928183	1.32	.796632	4.68	.203368	57
4	.725017	3.37	.928104	1.32	.796913	4.68	.203087	56
5	9.725219	3.35	9.928025	1.32	9.797194	4.67	0.202806	55
6	.725420	3.37	.927946	1.32	.797474	4.68	.202526	54
7	.725622	3.35	.927867	1.33	.797755	4.68	.202245	53
8	.725823	3.35	.927787	1.32	.798036	4.67	.201964	52
9	.726024	3.35	.927708	1.32	.798316	4.67	.201684	51
10	9.726225	3.35	9.927629	1.33	9.798596	4.68	0.201404	50
11	.726426	3.33	.927549	1.32	.798877	4.67	.201123	49
12	.726626	3.35	.927470	1.33	.799157	4.67	.200843	48
13	.726827	3.33	.927390	1.33	.799437	4.67	.200563	47
14	.727027	3.35	.927310	1.32	.799717	4.67	.200283	46
15	9.727228	3.33	9.927231	1.33	9.799997	4.67	0.200003	45
16	.727428	3.33	.927151	1.33	.800277	4.67	.199723	44
17	.727628	3.33	.927071	1.33	.800557	4.65	.199443	43
18	.727828	3.32	.926991	1.33	.800836	4.67	.199164	42
19	.728027	3.33	.926911	1.33	.801116	4.67	.198884	41
20	9.728227	3.33	9.926831	1.33	9.801396	4.65	0.198604	40
21	.728427	3.32	.926751	1.33	.801675	4.67	.198325	39
22	.728626	3.32	.926671	1.33	.801955	4.65	.198045	38
23	.728825	3.32	.926591	1.33	.802234	4.65	.197766	37
24	.729024	3.32	.926511	1.33	.802513	4.65	.197487	36
25	9.729223	3.32	9.926431	1.33	9.802792	4.67	0.197208	35
26	.729422	3.32	.926351	1.35	.803072	4.65	.196928	34
27	.729621	3.32	.926270	1.33	.803351	4.65	.196649	33
28	.729820	3.30	.926190	1.33	.803630	4.65	.196370	32
29	.730018	3.32	.926110	1.35	.803909	4.63	.196091	31
30	9.730217	3.30	9.926029	1.33	9.804187	4.65	0.195813	30
31	.730415	3.30	.925949	1.35	.804466	4.65	.195534	29
32	.730613	3.30	.925868	1.33	.804745	4.63	.195255	28
33	.730811	3.30	.925788	1.35	.805023	4.65	.194977	27
34	.731009	3.28	.925707	1.35	.805302	4.63	.194698	26
35	9.731206	3.30	9.925626	1.35	9.805580	4.65	0.194420	25
36	.731404	3.30	.925545	1.33	.805859	4.63	.194141	24
37	.731602	3.28	.925465	1.35	.806137	4.63	.193863	23
38	.731799	3.28	.925384	1.35	.806415	4.63	.193585	22
39	.731996	3.28	.925303	1.35	.806693	4.63	.193307	21
40	9.732193	3.28	9.925222	1.35	9.806971	4.63	0.193029	20
41	.732390	3.28	.925141	1.35	.807249	4.63	.192751	19
42	.732587	3.28	.925060	1.35	.807527	4.63	.192473	18
43	.732784	3.27	.924979	1.37	.807805	4.63	.192195	17
44	.732980	3.28	.924897	1.35	.808083	4.63	.191917	16
45	9.733177	3.27	9.924816	1.35	9.808361	4.62	0.191639	15
46	.733373	3.27	.924735	1.35	.808638	4.63	.191362	14
47	.733569	3.27	.924654	1.37	.808916	4.62	.191084	13
48	.733765	3.27	.924572	1.35	.809193	4.63	.190807	12
49	.733961	3.27	.924491	1.37	.809471	4.62	.190529	11
50	9.734157	3.27	9.924409	1.35	9.809748	4.62	0.190252	10
51	.734353	3.27	.924328	1.37	.810025	4.62	.189975	9
52	.734549	3.25	.924246	1.37	.810302	4.63	.189698	8
53	.734744	3.25	.924164	1.35	.810580	4.62	.189420	7
54	.734939	3.27	.924083	1.37	.810857	4.62	.189143	6
55	9.735135	3.25	9.924001	1.37	9.811134	4.60	0.188866	5
56	.735330	3.25	.923919	1.37	.811410	4.62	.188590	4
57	.735525	3.23	.923837	1.37	.811687	4.62	.188313	3
58	.735719	3.25	.923755	1.37	.811964	4.62	.188036	2
59	.735914	3.25	.923673	1.37	.812241	4.60	.187759	1
60	9.736109		9.923591		9.812517		0.187483	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.736109	3.23	9.923591	1.37	9.812517	4.62	0.187483	60
1	.736303	3.25	.923509	1.37	.812794	4.60	.187206	59
2	.736498	3.23	.923427	1.37	.813070	4.62	.186930	58
3	.736692	3.23	.923345	1.37	.813347	4.60	.186653	57
4	.736886	3.23	.923263	1.37	.813623	4.60	.186377	56
5	9.737080	3.23	9.923181	1.38	9.813899	4.62	0.186101	55
6	.737274	3.22	.923098	1.37	.814176	4.60	.185824	54
7	.737467	3.23	.923016	1.38	.814452	4.60	.185548	53
8	.737661	3.23	.922933	1.37	.814728	4.60	.185272	52
9	.737855	3.22	.922851	1.38	.815004	4.60	.184996	51
10	9.738048	3.22	9.922768	1.37	9.815280	4.58	0.184720	50
11	.738241	3.22	.922686	1.38	.815555	4.60	.184445	49
12	.738434	3.22	.922603	1.38	.815831	4.60	.184169	48
13	.738627	3.22	.922520	1.37	.816107	4.58	.183893	47
14	.738820	3.22	.922438	1.38	.816382	4.60	.183618	46
15	9.739013	3.22	9.922355	1.38	9.816658	4.58	0.183342	45
16	.739206	3.20	.922272	1.38	.816933	4.60	.183067	44
17	.739398	3.20	.922189	1.38	.817209	4.58	.182791	43
18	.739590	3.22	.922106	1.38	.817484	4.58	.182516	42
19	.739783	3.20	.922023	1.38	.817759	4.60	.182241	41
20	9.739975	3.20	9.921940	1.38	9.818035	4.58	0.181965	40
21	.740167	3.20	.921857	1.38	.818310	4.58	.181690	39
22	.740359	3.18	.921774	1.38	.818585	4.58	.181415	38
23	.740550	3.20	.921691	1.40	.818860	4.58	.181140	37
24	.740742	3.20	.921607	1.38	.819135	4.58	.180865	36
25	9.740934	3.18	9.921524	1.38	9.819410	4.57	0.180590	35
26	.741125	3.18	.921441	1.40	.819684	4.58	.180316	34
27	.741316	3.20	.921357	1.38	.819959	4.58	.180041	33
28	.741508	3.18	.921274	1.40	.820234	4.57	.179766	32
29	.741699	3.17	.921190	1.38	.820508	4.58	.179492	31
30	9.741889	3.18	9.921107	1.40	9.820783	4.57	0.179217	30
31	.742080	3.18	.921023	1.40	.821057	4.58	.178943	29
32	.742271	3.18	.920939	1.38	.821332	4.57	.178668	28
33	.742462	3.17	.920856	1.40	.821606	4.57	.178394	27
34	.742652	3.17	.920772	1.40	.821880	4.57	.178120	26
35	9.742842	3.18	9.920688	1.40	9.822154	4.58	0.177846	25
36	.743033	3.17	.920604	1.40	.822429	4.57	.177571	24
37	.743223	3.17	.920520	1.40	.822703	4.57	.177297	23
38	.743413	3.15	.920436	1.40	.822977	4.57	.177023	22
39	.743602	3.17	.920352	1.40	.823251	4.55	.176749	21
40	9.743792	3.17	9.920268	1.40	9.823524	4.57	0.176476	20
41	.743982	3.15	.920184	1.42	.823798	4.57	.176202	19
42	.744171	3.17	.920099	1.40	.824072	4.55	.175928	18
43	.744361	3.15	.920015	1.40	.824345	4.57	.175655	17
44	.744550	3.15	.919931	1.42	.824619	4.57	.175381	16
45	9.744739	3.15	9.919846	1.40	9.824893	4.55	0.175107	15
46	.744928	3.15	.919762	1.42	.825166	4.55	.174834	14
47	.745117	3.15	.919677	1.40	.825439	4.57	.174561	13
48	.745306	3.13	.919593	1.42	.825713	4.55	.174287	12
49	.745494	3.15	.919508	1.40	.825986	4.55	.174014	11
50	9.745683	3.13	9.919424	1.42	9.826259	4.55	0.173741	10
51	.745871	3.15	.919339	1.42	.826532	4.55	.173468	9
52	.746060	3.13	.919254	1.42	.826805	4.55	.173195	8
53	.746248	3.13	.919169	1.40	.827078	4.55	.172922	7
54	.746436	3.13	.919085	1.42	.827351	4.55	.172649	6
55	9.746624	3.13	9.919000	1.42	9.827624	4.55	0.172376	5
56	.746812	3.12	.918915	1.42	.827897	4.55	.172103	4
57	.746999	3.13	.918830	1.42	.828170	4.53	.171830	3
58	.747187	3.12	.918745	1.43	.828442	4.55	.171558	2
59	.747374	3.13	.918659	1.42	.828715	4.53	.171285	1
60	9.747562		9.918574		9.828987		0.171013	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.747562	3.12	9.918574	1.42	9.828987	4.55	0.171013	60
1	.747749	3.12	.918489	1.42	.829260	4.53	.170740	59
2	.747936	3.12	.918404	1.43	.829532	4.55	.170468	58
3	.748123	3.12	.918318	1.42	.829805	4.53	.170195	57
4	.748310	3.12	.918233	1.43	.830077	4.53	.169923	56
5	9.748497	3.10	9.918147	1.42	9.830349	4.53	0.169651	55
6	.748683	3.12	.918062	1.43	.830621	4.53	.169379	54
7	.748870	3.10	.917976	1.42	.830893	4.53	.169107	53
8	.749056	3.12	.917891	1.43	.831165	4.53	.168835	52
9	.749243	3.10	.917805	1.43	.831437	4.53	.168563	51
10	9.749429	3.10	9.917719	1.42	9.831709	4.53	0.168291	50
11	.749615	3.10	.917634	1.43	.831981	4.53	.168019	49
12	.749801	3.10	.917548	1.43	.832253	4.53	.167747	48
13	.749987	3.08	.917462	1.43	.832525	4.52	.167475	47
14	.750172	3.10	.917376	1.43	.832796	4.53	.167204	46
15	9.750358	3.08	9.917290	1.43	9.833068	4.52	0.166932	45
16	.750543	3.10	.917204	1.43	.833339	4.53	.166661	44
17	.750729	3.08	.917118	1.43	.833611	4.52	.166389	43
18	.750914	3.08	.917032	1.43	.833882	4.53	.166118	42
19	.751099	3.08	.916946	1.45	.834154	4.52	.165846	41
20	9.751284	3.08	9.916859	1.43	9.834425	4.52	0.165575	40
21	.751469	3.08	.916773	1.43	.834696	4.52	.165304	39
22	.751654	3.08	.916687	1.45	.834967	4.52	.165033	38
23	.751839	3.07	.916600	1.43	.835238	4.52	.164762	37
24	.752023	3.08	.916514	1.45	.835509	4.52	.164491	36
25	9.752208	3.07	9.916427	1.43	9.835780	4.52	0.164220	35
26	.752392	3.07	.916341	1.45	.836051	4.52	.163949	34
27	.752576	3.07	.916254	1.45	.836322	4.52	.163678	33
28	.752760	3.07	.916167	1.43	.836593	4.52	.163407	32
29	.752944	3.07	.916081	1.45	.836864	4.50	.163136	31
30	9.753128	3.07	9.915994	1.45	9.837134	4.52	0.162866	30
31	.753312	3.05	.915907	1.45	.837405	4.50	.162595	29
32	.753495	3.07	.915820	1.45	.837675	4.52	.162325	28
33	.753679	3.05	.915733	1.45	.837946	4.50	.162054	27
34	.753862	3.07	.915646	1.45	.838216	4.52	.161784	26
35	9.754046	3.05	9.915559	1.45	9.838487	4.50	0.161513	25
36	.754229	3.05	.915472	1.45	.838757	4.50	.161243	24
37	.754412	3.05	.915385	1.47	.839027	4.50	.160973	23
38	.754595	3.05	.915297	1.45	.839297	4.52	.160703	22
39	.754778	3.03	.915210	1.45	.839568	4.50	.160432	21
40	9.754960	3.05	9.915123	1.47	9.839838	4.50	0.160162	20
41	.755143	3.05	.915035	1.45	.840108	4.50	.159892	19
42	.755326	3.03	.914948	1.47	.840378	4.50	.159622	18
43	.755508	3.03	.914860	1.45	.840648	4.48	.159352	17
44	.755690	3.03	.914773	1.47	.840917	4.50	.159083	16
45	9.755872	3.03	9.914685	1.45	9.841187	4.50	0.158813	15
46	.756054	3.03	.914598	1.47	.841457	4.50	.158543	14
47	.756236	3.03	.914510	1.47	.841727	4.48	.158273	13
48	.756418	3.03	.914422	1.47	.841996	4.50	.158004	12
49	.756600	3.03	.914334	1.47	.842266	4.48	.157734	11
50	9.756782	3.02	9.914246	1.47	9.842535	4.50	0.157465	10
51	.756963	3.02	.914158	1.47	.842805	4.48	.157195	9
52	.757144	3.03	.914070	1.47	.843074	4.48	.156926	8
53	.757326	3.02	.913982	1.47	.843343	4.48	.156657	7
54	.757507	3.02	.913894	1.47	.843612	4.50	.156388	6
55	9.757688	3.02	9.913806	1.47	9.843882	4.48	0.156118	5
56	.757869	3.02	.913718	1.47	.844151	4.48	.155849	4
57	.758050	3.00	.913630	1.48	.844420	4.48	.155580	3
58	.758230	3.02	.913541	1.47	.844689	4.48	.155311	2
59	.758411	3.00	.913453	1.47	.844958	4.48	.155042	1
60	9.758591		9.913365		9.845227		0.154773	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.758591	3.02	9.913365	1.48	9.845227	4.48	0.154773	60
1	.758772	3.00	.913276	1.48	.845496	4.47	.154504	59
2	.758952	3.00	.913187	1.47	.845764	4.48	.154236	58
3	.759132	3.00	.913099	1.48	.846033	4.48	.153967	57
4	.759312	3.00	.913010	1.47	.846302	4.47	.153698	56
5	9.759492	3.00	9.912922	1.48	9.846570	4.48	0.153430	55
6	.759672	3.00	.912833	1.48	.846839	4.48	.153161	54
7	.759852	2.98	.912744	1.48	.847108	4.47	.152892	53
8	.760031	3.00	.912655	1.48	.847376	4.47	.152624	52
9	.760211	2.98	.912566	1.48	.847644	4.48	.152356	51
10	9.760390	2.98	9.912477	1.48	9.847913	4.47	0.152087	50
11	.760569	2.98	.912388	1.48	.848181	4.47	.151819	49
12	.760748	2.98	.912299	1.48	.848449	4.47	.151551	48
13	.760927	2.98	.912210	1.48	.848717	4.48	.151283	47
14	.761106	2.98	.912121	1.50	.848986	4.47	.151014	46
15	9.761285	2.98	9.912031	1.48	9.849254	4.47	0.150746	45
16	.761464	2.97	.911942	1.48	.849522	4.47	.150478	44
17	.761642	2.98	.911853	1.50	.849790	4.45	.150210	43
18	.761821	2.97	.911763	1.48	.850057	4.47	.149943	42
19	.761999	2.97	.911674	1.50	.850325	4.47	.149675	41
20	9.762177	2.98	9.911584	1.48	9.850593	4.47	0.149407	40
21	.762356	2.97	.911495	1.50	.850861	4.47	.149139	39
22	.762534	2.97	.911405	1.50	.851129	4.45	.148871	38
23	.762712	2.95	.911315	1.48	.851396	4.47	.148604	37
24	.762889	2.97	.911226	1.50	.851664	4.45	.148336	36
25	9.763067	2.97	9.911136	1.50	9.851931	4.47	0.148069	35
26	.763245	2.95	.911046	1.50	.852199	4.45	.147801	34
27	.763422	2.97	.910956	1.50	.852466	4.45	.147534	33
28	.763600	2.95	.910866	1.50	.852733	4.47	.147267	32
29	.763777	2.95	.910776	1.50	.853001	4.45	.146999	31
30	9.763954	2.95	9.910686	1.50	9.853268	4.45	0.146732	30
31	.764131	2.95	.910596	1.50	.853535	4.45	.146465	29
32	.764308	2.95	.910506	1.52	.853802	4.45	.146198	28
33	.764485	2.95	.910415	1.50	.854069	4.45	.145931	27
34	.764662	2.93	.910325	1.50	.854336	4.45	.145664	26
35	9.764838	2.95	9.910235	1.52	9.854603	4.45	0.145397	25
36	.765015	2.93	.910144	1.50	.854870	4.45	.145130	24
37	.765191	2.93	.910054	1.52	.855137	4.45	.144863	23
38	.765367	2.95	.909963	1.50	.855404	4.45	.144596	22
39	.765544	2.93	.909873	1.52	.855671	4.45	.144329	21
40	9.765720	2.93	9.909782	1.52	9.855938	4.43	0.144062	20
41	.765896	2.93	.909691	1.50	.856204	4.45	.143796	19
42	.766072	2.92	.909601	1.52	.856471	4.43	.143529	18
43	.766247	2.93	.909510	1.52	.856737	4.45	.143263	17
44	.766423	2.92	.909419	1.52	.857004	4.43	.142996	16
45	9.766598	2.93	9.909328	1.52	9.857270	4.45	0.142730	15
46	.766774	2.92	.909237	1.52	.857537	4.43	.142463	14
47	.766949	2.92	.909146	1.52	.857803	4.43	.142197	13
48	.767124	2.93	.909055	1.52	.858069	4.45	.141931	12
49	.767300	2.92	.908964	1.52	.858336	4.43	.141664	11
50	9.767475	2.90	9.908873	1.53	9.858602	4.43	0.141398	10
51	.767649	2.92	.908781	1.52	.858868	4.43	.141132	9
52	.767824	2.92	.908690	1.52	.859134	4.43	.140866	8
53	.767999	2.90	.908599	1.53	.859400	4.43	.140600	7
54	.768173	2.92	.908507	1.52	.859666	4.43	.140334	6
55	9.768348	2.90	9.908416	1.53	9.859932	4.43	0.140068	5
56	.768522	2.92	.908324	1.52	.860198	4.43	.139802	4
57	.768697	2.90	.908233	1.53	.860464	4.43	.139536	3
58	.768871	2.90	.908141	1.53	.860730	4.42	.139270	2
59	.769045	2.90	.908049	1.52	.860995	4.43	.139005	1
60	9.769219		9.907958		9.861261		0.138739	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.769219	2.90	9.907958	1.53	9.861261	4.43	0.138739	60
1	.769393	2.88	.907866	1.53	.861527	4.42	.138473	59
2	.769566	2.90	.907774	1.53	.861792	4.43	.138208	58
3	.769740	2.88	.907682	1.53	.862058	4.42	.137942	57
4	.769913	2.90	.907590	1.53	.862323	4.43	.137677	56
5	9.770087	2.88	9.907498	1.53	9.862589	4.42	0.137411	55
6	.770260	2.88	.907406	1.53	.862854	4.42	.137146	54
7	.770433	2.88	.907314	1.53	.863119	4.43	.136881	53
8	.770606	2.88	.907222	1.55	.863385	4.42	.136615	52
9	.770779	2.88	.907129	1.53	.863650	4.42	.136350	51
10	9.770952	2.88	9.907037	1.53	9.863915	4.42	0.136085	50
11	.771125	2.88	.906945	1.55	.864180	4.42	.135820	49
12	.771298	2.87	.906852	1.53	.864445	4.42	.135555	48
13	.771470	2.88	.906760	1.55	.864710	4.42	.135290	47
14	.771643	2.87	.906667	1.53	.864975	4.42	.135025	46
15	9.771815	2.87	9.906575	1.55	9.865240	4.42	0.134760	45
16	.771987	2.87	.906482	1.55	.865505	4.42	.134495	44
17	.772159	2.87	.906389	1.55	.865770	4.42	.134230	43
18	.772331	2.87	.906296	1.53	.866035	4.42	.133965	42
19	.772503	2.87	.906204	1.55	.866300	4.40	.133700	41
20	9.772675	2.87	9.906111	1.55	9.866564	4.42	0.133436	40
21	.772847	2.85	.906018	1.55	.866829	4.42	.133171	39
22	.773018	2.87	.905925	1.55	.867094	4.40	.132906	38
23	.773190	2.85	.905832	1.55	.867358	4.42	.132642	37
24	.773361	2.87	.905739	1.57	.867623	4.40	.132377	36
25	9.773533	2.85	9.905645	1.55	9.867887	4.42	0.132113	35
26	.773704	2.85	.905552	1.55	.868152	4.40	.131848	34
27	.773875	2.85	.905459	1.55	.868416	4.40	.131584	33
28	.774046	2.85	.905366	1.57	.868680	4.42	.131320	32
29	.774217	2.85	.905272	1.55	.868945	4.40	.131055	31
30	9.774388	2.83	9.905179	1.57	9.869209	4.40	0.130791	30
31	.774558	2.85	.905085	1.55	.869473	4.40	.130527	29
32	.774729	2.83	.904992	1.57	.869737	4.40	.130263	28
33	.774899	2.85	.904898	1.57	.870001	4.40	.129999	27
34	.775070	2.83	.904804	1.55	.870265	4.40	.129735	26
35	9.775240	2.83	9.904711	1.57	9.870529	4.40	0.129471	25
36	.775410	2.83	.904617	1.57	.870793	4.40	.129207	24
37	.775580	2.83	.904523	1.57	.871057	4.40	.128943	23
38	.775750	2.83	.904429	1.57	.871321	4.40	.128679	22
39	.775920	2.83	.904335	1.57	.871585	4.40	.128415	21
40	9.776090	2.82	9.904241	1.57	9.871849	4.38	0.128151	20
41	.776259	2.83	.904147	1.57	.872112	4.40	.127888	19
42	.776429	2.82	.904053	1.57	.872376	4.40	.127624	18
43	.776598	2.83	.903959	1.58	.872640	4.38	.127360	17
44	.776768	2.82	.903864	1.57	.872903	4.40	.127097	16
45	9.776937	2.82	9.903770	1.57	9.873167	4.38	0.126833	15
46	.777106	2.82	.903676	1.58	.873430	4.40	.126570	14
47	.777275	2.82	.903581	1.57	.873694	4.38	.126306	13
48	.777444	2.82	.903487	1.58	.873957	4.38	.126043	12
49	.777613	2.80	.903392	1.57	.874220	4.40	.125780	11
50	9.777781	2.82	9.903298	1.58	9.874484	4.38	0.125516	10
51	.777950	2.82	.903203	1.58	.874747	4.38	.125253	9
52	.778119	2.80	.903108	1.57	.875010	4.38	.124990	8
53	.778287	2.80	.903014	1.58	.875273	4.40	.124727	7
54	.778455	2.82	.902919	1.58	.875537	4.38	.124463	6
55	9.778624	2.80	9.902824	1.58	9.875800	4.38	0.124200	5
56	.778792	2.80	.902729	1.58	.876063	4.38	.123937	4
57	.778960	2.80	.902634	1.58	.876326	4.38	.123674	3
58	.779128	2.78	.902539	1.58	.876589	4.38	.123411	2
59	.779295	2.80	.902444	1.58	.876852	4.37	.123148	1
60	9.779463		9.902349		9.877114		0.122886	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.779463	2.80	9.902349	1.60	9.877114	4.38	0.122886	60
1	.779631	2.78	.902253	1.58	.877377	4.38	.122623	59
2	.779798	2.80	.902158	1.58	.877640	4.38	.122360	58
3	.779966	2.78	.902063	1.60	.877903	4.37	.122097	57
4	.780133	2.78	.901967	1.58	.878165	4.38	.121835	56
5	9.780300	2.78	9.901872	1.60	9.878428	4.38	0.121572	55
6	.780467	2.78	.901776	1.58	.878691	4.37	.121309	54
7	.780634	2.78	.901681	1.60	.878953	4.38	.121047	53
8	.780801	2.78	.901585	1.58	.879216	4.37	.120784	52
9	.780968	2.77	.901490	1.60	.879478	4.38	.120522	51
10	9.781134	2.78	9.901394	1.60	9.879741	4.37	0.120259	50
11	.781301	2.78	.901298	1.60	.880003	4.37	.119997	49
12	.781468	2.77	.901202	1.60	.880265	4.38	.119735	48
13	.781634	2.77	.901106	1.60	.880528	4.37	.119472	47
14	.781800	2.77	.901010	1.60	.880790	4.37	.119210	46
15	9.781966	2.77	9.900914	1.60	9.881052	4.37	0.118948	45
16	.782132	2.77	.900818	1.60	.881314	4.38	.118686	44
17	.782298	2.77	.900722	1.60	.881577	4.37	.118423	43
18	.782464	2.77	.900626	1.62	.881839	4.37	.118161	42
19	.782630	2.77	.900529	1.60	.882101	4.37	.117899	41
20	9.782796	2.75	9.900433	1.60	9.882363	4.37	0.117637	40
21	.782961	2.77	.900337	1.62	.882625	4.37	.117375	39
22	.783127	2.75	.900240	1.60	.882887	4.35	.117113	38
23	.783292	2.77	.900144	1.62	.883148	4.37	.116852	37
24	.783458	2.75	.900047	1.60	.883410	4.37	.116590	36
25	9.783623	2.75	9.899951	1.62	9.883672	4.37	0.116328	35
26	.783788	2.75	.899854	1.62	.883934	4.37	.116066	34
27	.783953	2.75	.899757	1.62	.884196	4.35	.115804	33
28	.784118	2.73	.899660	1.60	.884457	4.37	.115543	32
29	.784282	2.75	.899564	1.62	.884719	4.35	.115281	31
30	9.784447	2.75	9.899467	1.62	9.884980	4.37	0.115020	30
31	.784612	2.73	.899370	1.62	.885242	4.37	.114758	29
32	.784776	2.75	.899273	1.62	.885504	4.35	.114496	28
33	.784941	2.73	.899176	1.63	.885765	4.35	.114235	27
34	.785105	2.73	.899078	1.62	.886026	4.37	.113974	26
35	9.785269	2.73	9.898981	1.62	9.886288	4.35	0.113712	25
36	.785433	2.73	.898884	1.62	.886549	4.37	.113451	24
37	.785597	2.73	.898787	1.63	.886811	4.35	.113189	23
38	.785761	2.73	.898689	1.62	.887072	4.35	.112928	22
39	.785925	2.73	.898592	1.63	.887333	4.35	.112667	21
40	9.786089	2.72	9.898494	1.62	9.887594	4.35	0.112406	20
41	.786252	2.73	.898397	1.63	.887855	4.35	.112145	19
42	.786416	2.72	.898299	1.62	.888116	4.37	.111884	18
43	.786579	2.72	.898202	1.63	.888378	4.35	.111622	17
44	.786742	2.73	.898104	1.63	.888639	4.35	.111361	16
45	9.786906	2.72	9.898006	1.63	9.888900	4.35	0.111100	15
46	.787069	2.72	.897908	1.63	.889161	4.33	.110839	14
47	.787232	2.72	.897810	1.63	.889421	4.35	.110579	13
48	.787395	2.70	.897712	1.63	.889682	4.35	.110318	12
49	.787557	2.72	.897614	1.63	.889943	4.35	.110057	11
50	9.787720	2.72	9.897516	1.63	9.890204	4.35	0.109796	10
51	.787883	2.70	.897418	1.63	.890465	4.33	.109535	9
52	.788045	2.72	.897320	1.63	.890725	4.35	.109275	8
53	.788208	2.70	.897222	1.65	.890986	4.35	.109014	7
54	.788370	2.70	.897123	1.63	.891247	4.33	.108753	6
55	9.788532	2.70	9.897025	1.65	9.891507	4.35	0.108493	5
56	.788694	2.70	.896926	1.63	.891768	4.33	.108232	4
57	.788856	2.70	.896828	1.65	.892028	4.35	.107972	3
58	.789018	2.70	.896729	1.63	.892289	4.33	.107711	2
59	.789180	2.70	.896631	1.65	.892549	4.35	.107451	1
60	9.789342		9.896532		9.892810		0.107190	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.789342	2.70	9.896532	1.65	9.892810	4.33	0.107190	60
1	.789504	2.68	.896433	1.63	.893070	4.35	.106930	59
2	.789665	2.70	.896335	1.65	.893331	4.33	.106669	58
3	.789827	2.68	.896236	1.65	.893591	4.33	.106409	57
4	.789988	2.68	.896137	1.65	.893851	4.33	.106149	56
5	9.790149	2.68	9.896038	1.65	9.894111	4.35	0.105889	55
6	.790310	2.68	.895939	1.65	.894372	4.33	.105628	54
7	.790471	2.68	.895840	1.65	.894632	4.33	.105368	53
8	.790632	2.68	.895741	1.67	.894892	4.33	.105108	52
9	.790793	2.68	.895641	1.65	.895152	4.33	.104848	51
10	9.790954	2.68	9.895542	1.65	9.895412	4.33	0.104588	50
11	.791115	2.67	.895443	1.67	.895672	4.33	.104328	49
12	.791275	2.68	.895343	1.65	.895932	4.33	.104068	48
13	.791436	2.67	.895244	1.65	.896192	4.33	.103808	47
14	.791596	2.68	.895145	1.67	.896452	4.33	.103548	46
15	9.791757	2.67	9.895045	1.67	9.896712	4.32	0.103288	45
16	.791917	2.67	.894945	1.65	.896971	4.33	.103029	44
17	.792077	2.67	.894846	1.67	.897231	4.33	.102769	43
18	.792237	2.67	.894746	1.67	.897491	4.33	.102509	42
19	.792397	2.67	.894646	1.67	.897751	4.32	.102249	41
20	9.792557	2.65	9.894546	1.67	9.898010	4.33	0.101990	40
21	.792716	2.67	.894446	1.67	.898270	4.33	.101730	39
22	.792876	2.65	.894346	1.67	.898530	4.32	.101470	38
23	.793035	2.67	.894246	1.67	.898789	4.33	.101211	37
24	.793195	2.65	.894146	1.67	.899049	4.32	.100951	36
25	9.793354	2.67	9.894046	1.67	9.899308	4.33	0.100692	35
26	.793514	2.65	.893946	1.67	.899568	4.32	.100432	34
27	.793673	2.65	.893846	1.68	.899827	4.33	.100173	33
28	.793832	2.65	.893745	1.67	.900087	4.32	.099913	32
29	.793991	2.65	.893645	1.68	.900346	4.32	.099654	31
30	9.794150	2.63	9.893544	1.67	9.900605	4.32	0.099395	30
31	.794308	2.65	.893444	1.68	.900864	4.33	.099136	29
32	.794467	2.65	.893343	1.67	.901124	4.32	.098876	28
33	.794626	2.63	.893243	1.68	.901383	4.32	.098617	27
34	.794784	2.63	.893142	1.68	.901642	4.32	.098358	26
35	9.794942	2.65	9.893041	1.68	9.901901	4.32	0.098099	25
36	.795101	2.63	.892940	1.68	.902160	4.33	.097840	24
37	.795259	2.63	.892839	1.67	.902420	4.32	.097580	23
38	.795417	2.63	.892739	1.68	.902679	4.32	.097321	22
39	.795575	2.63	.892638	1.70	.902938	4.32	.097062	21
40	9.795733	2.63	9.892536	1.68	9.903197	4.32	0.096803	20
41	.795891	2.63	.892435	1.68	.903456	4.30	.096544	19
42	.796049	2.62	.892334	1.68	.903714	4.32	.096286	18
43	.796206	2.63	.892233	1.68	.903973	4.32	.096027	17
44	.796364	2.62	.892132	1.70	.904232	4.32	.095768	16
45	9.796521	2.63	9.892030	1.68	9.904491	4.32	0.095509	15
46	.796679	2.62	.891929	1.70	.904750	4.30	.095250	14
47	.796836	2.62	.891827	1.68	.905008	4.32	.094992	13
48	.796993	2.62	.891726	1.70	.905267	4.32	.094733	12
49	.797150	2.62	.891624	1.68	.905526	4.32	.094474	11
50	9.797307	2.62	9.891523	1.70	9.905785	4.30	0.094215	10
51	.797464	2.62	.891421	1.70	.906043	4.32	.093957	9
52	.797621	2.60	.891319	1.70	.906302	4.30	.093698	8
53	.797777	2.62	.891217	1.70	.906560	4.32	.093440	7
54	.797934	2.62	.891115	1.70	.906819	4.30	.093181	6
55	9.798091	2.60	9.891013	1.70	9.907077	4.32	0.092923	5
56	.798247	2.60	.890911	1.70	.907336	4.30	.092664	4
57	.798403	2.62	.890809	1.70	.907594	4.32	.092406	3
58	.798560	2.60	.890707	1.70	.907853	4.30	.092147	2
59	.798716	2.60	.890605	1.70	.908111	4.30	.091889	1
60	9.798872		9.890503		9.908369		0.091631	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.798872	2.60	9.890503	1.72	9.908369	4.32	0.091631	60
1	.799028	2.60	.890400	1.70	.908628	4.30	.091372	59
2	.799184	2.58	.890298	1.72	.908886	4.30	.091114	58
3	.799339	2.60	.890195	1.70	.909144	4.30	.090856	57
4	.799495	2.60	.890093	1.72	.909402	4.30	.090598	56
5	9.799651	2.58	9.889990	1.70	9.909660	4.30	0.090340	55
6	.799806	2.60	.889888	1.72	.909918	4.32	.090082	54
7	.799962	2.58	.889785	1.72	.910177	4.30	.089823	53
8	.800117	2.58	.889682	1.72	.910435	4.30	.089565	52
9	.800272	2.58	.889579	1.70	.910693	4.30	.089307	51
10	9.800427	2.58	9.889477	1.72	9.910951	4.30	0.089049	50
11	.800582	2.58	.889374	1.72	.911209	4.30	.088791	49
12	.800737	2.58	.889271	1.72	.911467	4.30	.088533	48
13	.800892	2.58	.889168	1.73	.911725	4.28	.088275	47
14	.801047	2.57	.889064	1.72	.911982	4.30	.088018	46
15	9.801201	2.58	9.888961	1.72	9.912240	4.30	0.087760	45
16	.801356	2.58	.888858	1.72	.912498	4.30	.087502	44
17	.801511	2.57	.888755	1.73	.912756	4.30	.087244	43
18	.801665	2.57	.888651	1.72	.913014	4.28	.086986	42
19	.801819	2.57	.888548	1.73	.913271	4.30	.086729	41
20	9.801973	2.58	9.888444	1.72	9.913529	4.30	0.086471	40
21	.802128	2.57	.888341	1.73	.913787	4.28	.086213	39
22	.802282	2.57	.888237	1.72	.914044	4.30	.085956	38
23	.802436	2.55	.888134	1.73	.914302	4.30	.085698	37
24	.802589	2.57	.888030	1.73	.914560	4.28	.085440	36
25	9.802743	2.57	9.887926	1.73	9.914817	4.30	0.085183	35
26	.802897	2.55	.887822	1.73	.915075	4.28	.084925	34
27	.803050	2.57	.887718	1.73	.915332	4.30	.084668	33
28	.803204	2.55	.887614	1.73	.915590	4.28	.084410	32
29	.803357	2.57	.887510	1.73	.915847	4.28	.084153	31
30	9.803511	2.55	9.887406	1.73	9.916104	4.30	0.083896	30
31	.803664	2.55	.887302	1.73	.916362	4.28	.083638	29
32	.803817	2.55	.887198	1.75	.916619	4.30	.083381	28
33	.803970	2.55	.887093	1.73	.916877	4.28	.083123	27
34	.804123	2.55	.886989	1.73	.917134	4.28	.082866	26
35	9.804276	2.53	9.886885	1.75	9.917391	4.28	0.082609	25
36	.804428	2.55	.886780	1.73	.917648	4.30	.082352	24
37	.804581	2.55	.886676	1.75	.917906	4.28	.082094	23
38	.804734	2.53	.886571	1.75	.918163	4.28	.081837	22
39	.804886	2.55	.886466	1.73	.918420	4.28	.081580	21
40	9.805039	2.53	9.886362	1.75	9.918677	4.28	0.081323	20
41	.805191	2.53	.886257	1.75	.918934	4.28	.081066	19
42	.805343	2.53	.886152	1.75	.919191	4.28	.080809	18
43	.805495	2.53	.886047	1.75	.919448	4.28	.080552	17
44	.805647	2.53	.885942	1.75	.919705	4.28	.080295	16
45	9.805799	2.53	9.885837	1.75	9.919962	4.28	0.080038	15
46	.805951	2.53	.885732	1.75	.920219	4.28	.079781	14
47	.806103	2.52	.885627	1.75	.920476	4.28	.079524	13
48	.806254	2.53	.885522	1.77	.920733	4.28	.079267	12
49	.806406	2.52	.885416	1.75	.920990	4.28	.079010	11
50	9.806557	2.53	9.885311	1.77	9.921247	4.27	0.078753	10
51	.806709	2.52	.885205	1.75	.921503	4.28	.078497	9
52	.806860	2.52	.885100	1.77	.921760	4.28	.078240	8
53	.807011	2.53	.884994	1.75	.922017	4.28	.077983	7
54	.807163	2.52	.884889	1.77	.922274	4.27	.077726	6
55	9.807314	2.52	9.884783	1.77	9.922530	4.28	0.077470	5
56	.807465	2.50	.884677	1.75	.922787	4.28	.077213	4
57	.807615	2.52	.884572	1.77	.923044	4.27	.076956	3
58	.807766	2.52	.884466	1.77	.923300	4.28	.076700	2
59	.807917	2.50	.884360	1.77	.923557	4.28	.076443	1
60	9.808067		9.884254		9.923814		0.076186	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.808067	2.52	9.884254	1.77	9.923814	4.27	0.076186	60
1	.808218	2.50	.884148	1.77	.924070	4.28	.075930	59
2	.808368	2.52	.884042	1.77	.924327	4.27	.075673	58
3	.808519	2.50	.883936	1.78	.924583	4.28	.075417	57
4	.808669	2.50	.883829	1.77	.924840	4.27	.075160	56
5	9.808819	2.50	9.883723	1.77	9.925096	4.27	0.074904	55
6	.808969	2.50	.883617	1.78	.925352	4.28	.074648	54
7	.809119	2.50	.883510	1.77	.925609	4.27	.074391	53
8	.809269	2.50	.883404	1.78	.925865	4.28	.074135	52
9	.809419	2.50	.883297	1.77	.926122	4.27	.073878	51
10	9.809569	2.48	9.883191	1.78	9.926378	4.27	0.073622	50
11	.809718	2.50	.883084	1.78	.926634	4.27	.073366	49
12	.809868	2.48	.882977	1.77	.926890	4.28	.073110	48
13	.810017	2.50	.882871	1.78	.927147	4.27	.072853	47
14	.810167	2.48	.882764	1.78	.927403	4.27	.072597	46
15	9.810316	2.48	9.882657	1.78	9.927659	4.27	0.072341	45
16	.810465	2.48	.882550	1.78	.927915	4.27	.072085	44
17	.810614	2.48	.882443	1.78	.928171	4.27	.071829	43
18	.810763	2.48	.882336	1.78	.928427	4.28	.071573	42
19	.810912	2.48	.882229	1.80	.928684	4.27	.071316	41
20	9.811061	2.48	9.882121	1.78	9.928940	4.27	0.071060	40
21	.811210	2.47	.882014	1.78	.929196	4.27	.070804	39
22	.811358	2.48	.881907	1.80	.929452	4.27	.070548	38
23	.811507	2.47	.881799	1.78	.929708	4.27	.070292	37
24	.811655	2.48	.881692	1.80	.929964	4.27	.070036	36
25	9.811804	2.47	9.881584	1.78	9.930220	4.25	0.069780	35
26	.811952	2.47	.881477	1.80	.930475	4.27	.069525	34
27	.812100	2.47	.881369	1.80	.930731	4.27	.069269	33
28	.812248	2.47	.881261	1.80	.930987	4.27	.069013	32
29	.812396	2.47	.881153	1.78	.931243	4.27	.068757	31
30	9.812544	2.47	9.881046	1.80	9.931499	4.27	0.068501	30
31	.812692	2.47	.880938	1.80	.931755	4.25	.068245	29
32	.812840	2.47	.880830	1.80	.932010	4.27	.067990	28
33	.812988	2.45	.880722	1.82	.932266	4.27	.067734	27
34	.813135	2.47	.880613	1.80	.932522	4.27	.067478	26
35	9.813283	2.45	9.880505	1.80	9.932778	4.25	0.067222	25
36	.813430	2.47	.880397	1.80	.933033	4.27	.066967	24
37	.813578	2.45	.880289	1.82	.933289	4.27	.066711	23
38	.813725	2.45	.880180	1.80	.933545	4.25	.066455	22
39	.813872	2.45	.880072	1.82	.933800	4.27	.066200	21
40	9.814019	2.45	9.879963	1.80	9.934056	4.25	0.065944	20
41	.814166	2.45	.879855	1.82	.934311	4.27	.065689	19
42	.814313	2.45	.879746	1.82	.934567	4.25	.065433	18
43	.814460	2.45	.879637	1.80	.934822	4.27	.065178	17
44	.814607	2.43	.879529	1.82	.935078	4.25	.064922	16
45	9.814753	2.45	9.879420	1.82	9.935333	4.27	0.064667	15
46	.814900	2.43	.879311	1.82	.935589	4.25	.064411	14
47	.815046	2.45	.879202	1.82	.935844	4.27	.064156	13
48	.815193	2.43	.879093	1.82	.936100	4.25	.063900	12
49	.815339	2.43	.878984	1.82	.936355	4.27	.063645	11
50	9.815485	2.45	9.878875	1.82	9.936611	4.25	0.063389	10
51	.815632	2.43	.878766	1.83	.936866	4.25	.063134	9
52	.815778	2.43	.878656	1.82	.937121	4.27	.062879	8
53	.815924	2.42	.878547	1.82	.937377	4.25	.062623	7
54	.816069	2.43	.878438	1.83	.937632	4.25	.062368	6
55	9.816215	2.43	9.878328	1.82	9.937887	4.25	0.062113	5
56	.816361	2.43	.878219	1.83	.938142	4.27	.061858	4
57	.816507	2.42	.878109	1.83	.938398	4.25	.061602	3
58	.816652	2.43	.877999	1.82	.938653	4.25	.061347	2
59	.816798	2.42	.877890	1.83	.938908	4.25	.061092	1
60	9.816943		9.877780		9.939163		0.060837	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.816943	2.42	9.877780	1.83	9.939163	4.25	0.060837	60
1	.817088	2.42	.877670	1.83	.939418	4.25	.060582	59
2	.817233	2.43	.877560	1.83	.939673	4.25	.060327	58
3	.817379	2.42	.877450	1.83	.939928	4.25	.060072	57
4	.817524	2.40	.877340	1.83	.940183	4.27	.059817	56
5	9.817668	2.42	9.877230	1.83	9.940439	4.25	0.059561	55
6	.817813	2.42	.877120	1.83	.940694	4.25	.059306	54
7	.817958	2.42	.877010	1.85	.940949	4.25	.059051	53
8	.818103	2.40	.876899	1.83	.941204	4.25	.058796	52
9	.818247	2.42	.876789	1.85	.941459	4.23	.058541	51
10	9.818392	2.40	9.876678	1.83	9.941713	4.25	0.058287	50
11	.818536	2.42	.876568	1.85	.941968	4.25	.058032	49
12	.818681	2.40	.876457	1.83	.942223	4.25	.057777	48
13	.818825	2.40	.876347	1.85	.942478	4.25	.057522	47
14	.818969	2.40	.876236	1.85	.942733	4.25	.057267	46
15	9.819113	2.40	9.876125	1.85	9.942988	4.25	0.057012	45
16	.819257	2.40	.876014	1.83	.943243	4.25	.056757	44
17	.819401	2.40	.875904	1.85	.943498	4.23	.056502	43
18	.819545	2.40	.875793	1.85	.943752	4.25	.056248	42
19	.819689	2.38	.875682	1.85	.944007	4.25	.055993	41
20	9.819832	2.40	9.875571	1.87	9.944262	4.25	0.055738	40
21	.819976	2.40	.875459	1.85	.944517	4.23	.055483	39
22	.820120	2.38	.875348	1.85	.944771	4.25	.055229	38
23	.820263	2.38	.875237	1.85	.945026	4.25	.054974	37
24	.820406	2.40	.875126	1.87	.945281	4.23	.054719	36
25	9.820550	2.38	9.875014	1.85	9.945535	4.25	0.054465	35
26	.820693	2.38	.874903	1.87	.945790	4.25	.054210	34
27	.820836	2.38	.874791	1.85	.946045	4.23	.053955	33
28	.820979	2.38	.874680	1.87	.946299	4.25	.053701	32
29	.821122	2.38	.874568	1.87	.946554	4.23	.053446	31
30	9.821265	2.37	9.874456	1.87	9.946808	4.25	0.053192	30
31	.821407	2.38	.874344	1.87	.947063	4.25	.052937	29
32	.821550	2.38	.874232	1.85	.947318	4.23	.052682	28
33	.821693	2.37	.874121	1.87	.947572	4.25	.052428	27
34	.821835	2.37	.874009	1.88	.947827	4.23	.052173	26
35	9.821977	2.38	9.873896	1.87	9.948081	4.23	0.051919	25
36	.822120	2.37	.873784	1.87	.948335	4.25	.051665	24
37	.822262	2.37	.873672	1.87	.948590	4.23	.051410	23
38	.822404	2.37	.873560	1.87	.948844	4.25	.051156	22
39	.822546	2.37	.873448	1.88	.949099	4.23	.050901	21
40	9.822688	2.37	9.873335	1.87	9.949353	4.25	0.050647	20
41	.822830	2.37	.873223	1.88	.949608	4.23	.050392	19
42	.822972	2.37	.873110	1.87	.949862	4.23	.050138	18
43	.823114	2.35	.872998	1.88	.950116	4.25	.049884	17
44	.823255	2.37	.872885	1.88	.950371	4.23	.049629	16
45	9.823397	2.37	9.872772	1.88	9.950625	4.23	0.049375	15
46	.823539	2.35	.872659	1.87	.950879	4.23	.049121	14
47	.823680	2.35	.872547	1.88	.951133	4.25	.048867	13
48	.823821	2.37	.872434	1.88	.951388	4.23	.048612	12
49	.823963	2.35	.872321	1.88	.951642	4.23	.048358	11
50	9.824104	2.35	9.872208	1.88	9.951896	4.23	0.048104	10
51	.824245	2.35	.872095	1.90	.952150	4.25	.047850	9
52	.824386	2.35	.871981	1.88	.952405	4.23	.047595	8
53	.824527	2.35	.871868	1.88	.952659	4.23	.047341	7
54	.824668	2.33	.871755	1.90	.952913	4.23	.047087	6
55	9.824808	2.35	9.871641	1.88	9.953167	4.23	0.046833	5
56	.824949	2.35	.871528	1.90	.953421	4.23	.046579	4
57	.825090	2.33	.871414	1.88	.953675	4.23	.046325	3
58	.825230	2.35	.871301	1.90	.953929	4.23	.046071	2
59	.825371	2.33	.871187	1.90	.954183	4.23	.045817	1
60	9.825511		9.871073		9.954437		0.045563	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.825511	2.33	9.871073	1.88	9.954437	4.23	0.045563	60
1	.825651	2.33	.870960	1.90	.954691	4.25	.045309	59
2	.825791	2.33	.870846	1.90	.954946	4.23	.045054	58
3	.825931	2.33	.870732	1.90	.955200	4.23	.044800	57
4	.826071	2.33	.870618	1.90	.955454	4.23	.044546	56
5	9.826211	2.33	9.870504	1.90	9.955708	4.22	0.044292	55
6	.826351	2.33	.870390	1.90	.955961	4.23	.044039	54
7	.826491	2.33	.870276	1.92	.956215	4.23	.043785	53
8	.826631	2.32	.870161	1.90	.956469	4.23	.043531	52
9	.826770	2.33	.870047	1.90	.956723	4.23	.043277	51
10	9.826910	2.32	9.869933	1.92	9.956977	4.23	0.043023	50
11	.827049	2.33	.869818	1.90	.957231	4.23	.042769	49
12	.827189	2.32	.869704	1.92	.957485	4.23	.042515	48
13	.827328	2.32	.869589	1.92	.957739	4.23	.042261	47
14	.827467	2.32	.869474	1.90	.957993	4.23	.042007	46
15	9.827606	2.32	9.869360	1.92	9.958247	4.22	0.041753	45
16	.827745	2.32	.869245	1.92	.958500	4.23	.041500	44
17	.827884	2.32	.869130	1.92	.958754	4.23	.041246	43
18	.828023	2.32	.869015	1.92	.959008	4.23	.040992	42
19	.828162	2.32	.868900	1.92	.959262	4.23	.040738	41
20	9.828301	2.30	9.868785	1.92	9.959516	4.22	0.040484	40
21	.828439	2.32	.868670	1.92	.959769	4.23	.040231	39
22	.828578	2.30	.868555	1.92	.960023	4.23	.039977	38
23	.828716	2.32	.868440	1.93	.960277	4.22	.039723	37
24	.828855	2.30	.868324	1.92	.960530	4.23	.039470	36
25	9.828993	2.30	9.868209	1.93	9.960784	4.23	0.039216	35
26	.829131	2.30	.868093	1.92	.961038	4.23	.038962	34
27	.829269	2.30	.867978	1.93	.961292	4.22	.038708	33
28	.829407	2.30	.867862	1.92	.961545	4 23	.038455	32
29	.829545	2.30	.867747	1.93	.961799	4.22	.038201	31
30	9.829683	2.30	9.867631	1.93	9.962052	4.23	0.037948	30
31	.829821	2.30	.867515	1.93	.962306	4.23	.037694	29
32	.829959	2.30	.867399	1.93	.962560	4.22	.037440	28
33	.830097	2.28	.867283	1.93	.962813	4.23	.037187	27
34	.830234	2.30	.867167	1.93	.963067	4.22	.036933	26
35	9.830372	2.28	9.867051	1.93	9.963320	4.23	0.036680	25
36	.830509	2.28	.866935	1.93	.963574	4.23	.036426	24
37	.830646	2.30	.866819	1.93	.963828	4.22	.036172	23
38	.830784	2.28	.866703	1.95	.964081	4.23	.035919	22
39	.830921	2.28	.866586	1.93	.964335	4.22	.035665	21
40	9.831058	2.28	9.866470	1.95	9.964588	4.23	0.035412	20
41	.831195	2.28	.866353	1.93	.964842	4.22	.035158	19
42	.831332	2.28	.866237	1.95	.965095	4.23	.034905	18
43	.831469	2.28	.866120	1.93	.965349	4.22	.034651	17
44	.831606	2.27	.866004	1.95	.965602	4.22	.034398	16
45	9.831742	2.28	9.865887	1.95	9.965855	4.23	0.034145	15
46	.831879	2.27	.865770	1.95	.966109	4.22	.033891	14
47	.832015	2.28	.865653	1.95	.966362	4.23	.033638	13
48	.832152	2.27	.865536	1.95	.966616	4.22	.033384	12
49	.832288	2.28	.865419	1.95	.966869	4.23	.033131	11
50	9.832425	2.27	9.865302	1.95	9.967123	4.22	0.032877	10
51	.832561	2.27	.865185	1.95	.967376	4.22	.032624	9
52	.832697	2.27	.865068	1.97	.967629	4.23	.032371	8
53	.832833	2.27	.864950	1.95	.967883	4.22	.032117	7
54	.832969	2.27	.864833	1.95	.968136	4.22	.031864	6
55	9.833105	2.27	9.864716	1.97	9.968389	4.23	0.031611	5
56	.833241	2.27	.864598	1.95	.968643	4.22	.031357	4
57	.833377	2.25	.864481	1.97	.968896	4.22	.031104	3
58	.833512	2.27	.864363	1.97	.969149	4.23	.030851	2
59	.833648	2.25	.864245	1.97	.969403	4.22	.030597	1
60	9.833783		9.864127		9.969656		0.030344	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.833783	2.27	9.864127	1.95	9.969656	4.22	0.030344	60
1	.833919	2.25	.864010	1.97	.969909	4.22	.030091	59
2	.834054	2.25	.863892	1.97	.970162	4.23	.029838	58
3	.834189	2.27	.863774	1.97	.970416	4.22	.029584	57
4	.834325	2.25	.863656	1.97	.970669	4.22	.029331	56
5	9.834460	2.25	9.863538	1.98	9.970922	4.22	0.029078	55
6	.834595	2.25	.863419	1.97	.971175	4.23	.028825	54
7	.834730	2.25	.863301	1.97	.971429	4.22	.028571	53
8	.834865	2.23	.863183	1.98	.971682	4.22	.028318	52
9	.834999	2.25	.863064	1.97	.971935	4.22	.028065	51
10	9.835134	2.25	9.862946	1.98	9.972188	4.22	0.027812	50
11	.835269	2.23	.862827	1.97	.972441	4.23	.027559	49
12	.835403	2.25	.862709	1.98	.972695	4.22	.027305	48
13	.835538	2.23	.862590	1.98	.972948	4.22	.027052	47
14	.835672	2.25	.862471	1.97	.973201	4.22	.026799	46
15	9.835807	2.23	9.862353	1.98	9.973454	4.22	0.026546	45
16	.835941	2.23	.862234	1.98	.973707	4.22	.026293	44
17	.836075	2.23	.862115	1.98	.973960	4.22	.026040	43
18	.836209	2.23	.861996	1.98	.974213	4.22	.025787	42
19	.836343	2.23	.861877	1.98	.974466	4.23	.025534	41
20	9.836477	2.23	9.861758	2.00	9.974720	4.22	0.025280	40
21	.836611	2.23	.861638	1.98	.974973	4.22	.025027	39
22	.836745	2.22	.861519	1.98	.975226	4.22	.024774	38
23	.836878	2.23	.861400	2.00	.975479	4.22	.024521	37
24	.837012	2.23	.861280	1.98	.975732	4.22	.024268	36
25	9.837146	2.22	9.861161	2.00	9.975985	4.22	0.024015	35
26	.837279	2.22	.861041	1.98	.976238	4.22	.023762	34
27	.837412	2.23	.860922	2.00	.976491	4.22	.023509	33
28	.837546	2.22	.860802	2.00	.976744	4.22	.023256	32
29	.837679	2.22	.860682	2.00	.976997	4.22	.023003	31
30	9.837812	2.22	9.860562	2.00	9.977250	4.22	0.022750	30
31	.837945	2.22	.860442	2.00	.977503	4.22	.022497	29
32	.838078	2.22	.860322	2.00	.977756	4.22	.022244	28
33	.838211	2.22	.860202	2.00	.978009	4.22	.021991	27
34	.838344	2.22	.860082	2.00	.978262	4.22	.021738	26
35	9.838477	2.22	9.859962	2.00	9.978515	4.22	0.021485	25
36	.838610	2.20	.859842	2.02	.978768	4.22	.021232	24
37	.838742	2.22	.859721	2.00	.979021	4.22	.020979	23
38	.838875	2.20	.859601	2.02	.979274	4.22	.020726	22
39	.839007	2.22	.859480	2.00	.979527	4.22	.020473	21
40	9.839140	2.20	9.859360	2.02	9.979780	4.22	0.020220	20
41	.839272	2.20	.859239	2.00	.980033	4.22	.019967	19
42	.839404	2.20	.859119	2.02	.980286	4.20	.019714	18
43	.839536	2.20	.858998	2.02	.980538	4.22	.019462	17
44	.839668	2.20	.858877	2.02	.980791	4.22	.019209	16
45	9.839800	2.20	9.858756	2.02	9.981044	4.22	0.018956	15
46	.839932	2.20	.858635	2.02	.981297	4.22	.018703	14
47	.840064	2.20	.858514	2.02	.981550	4.22	.018450	13
48	.840196	2.20	.858393	2.02	.981803	4.22	.018197	12
49	.840328	2.18	.858272	2.02	.982056	4.22	.017944	11
50	9.840459	2.20	9.858151	2.03	9.982309	4.22	0.017691	10
51	.840591	2.18	.858029	2.02	.982562	4.20	.017438	9
52	.840722	2.20	.857908	2.03	.982814	4.22	.017186	8
53	.840854	2.18	.857786	2.02	.983067	4.22	.016933	7
54	.840985	2.18	.857665	2.03	.983320	4.22	.016680	6
55	9.841116	2.18	9.857543	2.02	9.983573	4.22	0.016427	5
56	.841247	2.18	.857422	2.03	.983826	4.22	.016174	4
57	.841378	2.18	.857300	2.03	.984079	4.22	.015921	3
58	.841509	2.18	.857178	2.03	.984332	4.20	.015668	2
59	.841640	2.18	.857056	2.03	.984584	4.22	.015416	1
60	9.841771		9.856934		9.984837		0.015163	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.841771	2.18	9.856934	2.03	9.984837	4.22	0.015163	60
1	.841902	2.18	.856812	2.03	.985090	4.22	.014910	59
2	.842033	2.17	.856690	2.03	.985343	4.22	.014657	58
3	.842163	2.18	.856568	2.03	.985596	4.20	.014404	57
4	.842294	2.17	.856446	2.05	.985848	4.22	.014152	56
5	9.842424	2.18	9.856323	2.03	9.986101	4.22	0.013899	55
6	.842555	2.17	.856201	2.05	.986354	4.22	.013646	54
7	.842685	2.17	.856078	2.03	.986607	4.22	.013393	53
8	.842815	2.18	.855956	2.05	.986860	4.20	.013140	52
9	.842946	2.17	.855833	2.03	.987112	4.22	.012888	51
10	9.843076	2.17	9.855711	2.05	9.987365	4.22	0.012635	50
11	.843206	2.17	.855588	2.05	.987618	4.22	.012382	49
12	.843336	2.17	.855465	2.05	.987871	4.20	.012129	48
13	.843466	2.15	.855342	2.05	.988123	4.22	.011877	47
14	.843595	2.17	.855219	2.05	.988376	4.22	.011624	46
15	9.843725	2.17	9.855096	2.05	9.988629	4.22	0.011371	45
16	.843855	2.15	.854973	2.05	.988882	4.20	.011118	44
17	.843984	2.17	.854850	2.05	.989134	4.22	.010866	43
18	.844114	2.15	.854727	2.07	.989387	4.22	.010613	42
19	.844243	2.15	.854603	2.05	.989640	4.22	.010360	41
20	9.844372	2.17	9.854480	2.07	9.989893	4.20	0.010107	40
21	.844502	2.15	.854356	2.05	.990145	4.22	.009855	39
22	.844631	2.15	.854233	2.07	.990398	4.22	.009602	38
23	.844760	2.15	.854109	2.05	.990651	4.20	.009349	37
24	.844889	2.15	.853986	2.07	.990903	4.22	.009097	36
25	9.845018	2.15	9.853862	2.07	9.991156	4.22	0.008844	35
26	.845147	2.15	.853738	2.07	.991409	4.22	.008591	34
27	.845276	2.15	.853614	2.07	.991662	4.20	.008338	33
28	.845405	2.13	.853490	2.07	.991914	4.22	.008086	32
29	.845533	2.15	.853366	2.07	.992167	4.22	.007833	31
30	9.845662	2.13	9.853242	2.07	9.992420	4.20	0.007580	30
31	.845790	2.15	.853118	2.07	.992672	4.22	.007328	29
32	.845919	2.13	.852994	2.08	.992925	4.22	.007075	28
33	.846047	2.13	.852869	2.07	.993178	4.22	.006822	27
34	.846175	2.15	.852745	2.08	.993431	4.20	.006569	26
35	9.846304	2.13	9.852620	2.07	9.993683	4.22	0.006317	25
36	.846432	2.13	.852496	2.08	.993936	4.22	.006064	24
37	.846560	2.13	.852371	2.07	.994189	4.20	.005811	23
38	.846688	2.13	.852247	2.08	.994441	4.22	.005559	22
39	.846816	2.13	.852122	2.08	.994694	4.22	.005306	21
40	9.846944	2.12	9.851997	2.08	9.994947	4.20	0.005053	20
41	.847071	2.13	.851872	2.08	.995199	4.22	.004801	19
42	.847199	2.13	.851747	2.08	.995452	4.22	.004548	18
43	.847327	2.12	.851622	2.08	.995705	4.20	.004295	17
44	.847454	2.13	.851497	2.08	.995957	4.22	.004043	16
45	9.847582	2.12	9.851372	2.10	9.996210	4.22	0.003790	15
46	.847709	2.12	.851246	2.08	.996463	4.20	.003537	14
47	.847836	2.13	.851121	2.08	.996715	4.22	.003285	13
48	.847964	2.12	.850996	2.10	.996968	4.22	.003032	12
49	.848091	2.12	.850870	2.08	.997221	4.20	.002779	11
50	9.848218	2.12	9.850745	2.10	9.997473	4.22	0.002527	10
51	.848345	2.12	.850619	2.10	.997726	4.22	.002274	9
52	.848472	2.12	.850493	2.08	.997979	4.20	.002021	8
53	.848599	2.12	.850368	2.10	.998231	4.22	.001769	7
54	.848726	2.10	.850242	2.10	.998484	4.22	.001516	6
55	9.848852	2.12	9.850116	2.10	9.998737	4.20	0.001263	5
56	.848979	2.12	.849990	2.10	.998989	4.22	.001011	4
57	.849106	2.10	.849864	2.10	.999242	4.22	.000758	3
58	.849232	2.12	.849738	2.12	.999495	4.20	.000505	2
59	.849359	2.10	.849611	2.10	.999747	4.22	.000253	1
60	9.849485		9.849485		0.000000		0.000000	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

TABLE 63. GIVING THE WEIGHTS OF DIFFERENT MATERIALS PER CUBIC FOOT[1]

MATERIAL	Weight per Cu. Ft.
Ash timber	40 lbs.
Brick (pressed)	150 "
" (common building)	125 "
Cement (Portland)	75 to 90 "
" (Natural	50 to 56 "
Concrete 1: 2: 4 Mixture (Trap rock)	155 "
" (Gravel)	152 "
" (Limestone)	150 "
" (Sandstone)	145 "
" (Cinder)	110 "
" 1: 3: 6 Mixture (about 5 lbs. less)	— "
Earth (common loam, loose and dry)	70 "
" (common loam, moist and rammed)	100 "
" (sand or gravel loose and dry)	100 "
" (sand or gravel rammed)	120 "
" (sand or gravel wet)	120 "
Hemlock timber	25 "
Hickory "	50 "
Iron (cast)	450 "
" (wrought)	480 "
Maple timber	50 "
Oak " (white)	48 "
" " (black)	40 "
Masonry (dressed granite or limestone)	165 "
" (mortar rubble)	155 "
" (dry ")	125 "
Pine (white)	25 "
" (northern yellow)	34 "
" (southern yellow)	40 "
Steel	490 "
Water	62.5 "

Miscellaneous Weights

1 bbl. Portland cement	376	lbs.
1 " natural "	235	"
1 gal. water "	8.345	"

[1] For weight of road rocks, see Tables 21 and 22, page 99.

TABLE 64. GIVING MODULI OF ELASTICITY, WORKING STRESS AND ULTIMATE STRENGTH

MODULI OF ELASTICITY

Material	Lbs. per Sq. In.
Concrete	2,000,000
Hemlock	900,000
Iron (cast)	17,500,000
Iron (wrought)	29,000,000
Oak	1,500,000
Pine (white)	1,600,000
Pine (yellow)	1,600,000
Steel (medium)	30,000,000
Spruce	1,600,000

WORKING STRESSES IN LBS. PER SQUARE INCH

Material	Tension	Compression	Shear
Concrete	60	600	60 to 100
Hemlock	600	W. G.[1] 600 A. G.[2] 150	W. G. 100 A. G. 600
Iron (cast)	3,000	18,000	5,000
" (wrought)	10,000	8,000	8,000
Oak	1,200	W. G. 1,200 A. G. 500	W. G. 200 A. G. 1,000
Pine (white)	700	W. G. 700 A. G. 200	W. G. 100 A. G. 500
" (yellow)	1,200	W. G. 1,200 A. G. 350	W. G. 150 A. G. 1,250
Steel (medium)	12,000	12,000	12,000
Spuce	800	W G. 800 A. G. 200	W. G. 100 A. G. 750

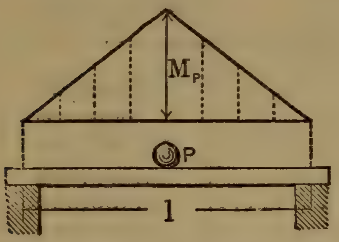
ULTIMATE STRENGTH IN LBS. PER SQUARE INCH

Material	Tension	Compression	Shear
Concrete	300	3,000	1300
Hemlock	6,000	W. G. 6,000 A. G. 600	W. G. 350 A. G. 2,500
Iron (cast)	18,000	90.000	20,000 to 30,000
" (wrought)	50,000	40,000	35,000 to 55,000
Oak	12,000	W. G 7,000 A. G. 2,000	W. G. 800 A. G. 4,000
Pine (white)	7,000	W G. 5,500 A. G. 700	W. G 400 A. G. 2,000
" (yellow)	12,000	W. G. 7,000 A. G. 1,400	W. G. 600 A. G. 5,000
Steel (medium)	60,000	60,000	50,000 to 70,000
Spruce	8,000	W. G. 6,000 A. G. 700	W. G. 400 A. G. 3,200

[1] W. G. — With Grain. [2] A. G. — Across Grain.

Table 65. Uniform Beams. Maximum Bending Moment and Deflections (Simple Cases)

Case 1. Beam with ends free. Single concentrated load P in middle of span; weight of beam disregarded.



Concentrated Load in Center of span

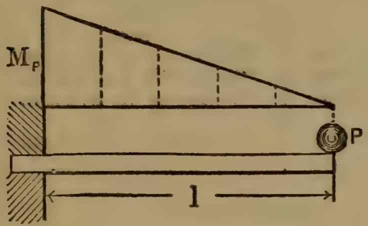
The maximum moment occurs at the center of the span.

$$M_p = \frac{Pl}{4}$$

The maximum deflection occurs at the center of the span.

$$D = \frac{Pl^3}{48\,EI}$$

Where D = the deflection in inches
P = load in pounds
l = span in inches
E = modulus of elasticity in lbs. per sq. inch
I = moment of inertia in inches^4
M_p = maximum moment in inch pounds.



Cantilever Beam

Case 2. Cantilever beam concentrated load P; weight of beam disregarded.

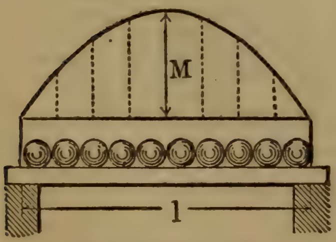
The maximum moment occurs at the support.

$$M_p = Pl$$

$$D = \frac{Pl^3}{3\,EI}$$

Case 3. Beam with ends free. Uniformly distributed load. The maximum moment occurs at the center of the span.

$$M = \frac{Wl}{8}$$



Uniform Load

The maximum deflection occurs at the center of the span.

$$D = \frac{5}{384}\,\frac{Wl^3}{EI}$$

In these formulæ W equals the total uniformly distributed load.

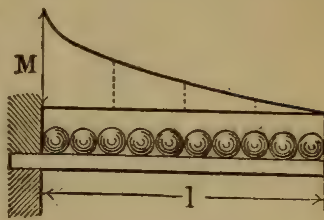
Case 4. Cantilever beam. Uniform load W.

Maximum moment occurs at the point of support.

$$M = \frac{Wl}{2}$$

The maximum deflection occurs at the free end.

$$D = \frac{Wl^3}{8\,EI}$$

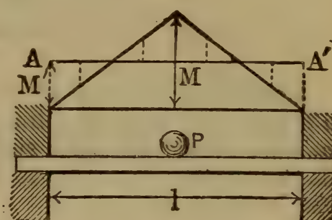


Case 5. Beam with fixed ends, concentrated load P in center of span; weight of beam disregarded.

The maximum bending moment occurs at the points of support and at the middle of the beam.

$$M = \frac{Pl}{8}$$

$$D = \frac{Pl^3}{192\,EI}$$



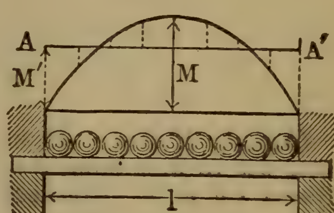
Case 6. Beam with fixed ends and a uniformly distributed load. Maximum bending moment occurs at the supports.

$$M' = \frac{Wl}{12}$$

$$M = \frac{Wl}{24}$$

Maximum deflection

$$= \frac{Wl^3}{384\,EI}$$



Resisting Moment of a beam is expressed by the formula

$$M_r = \frac{pI}{e}$$

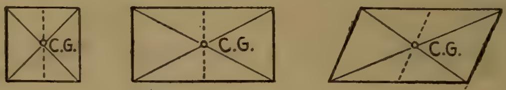
Where M_r = moment of resistance in inch pounds

p = maximum allowable fiber stress in lbs. per sq. inch.

I = moment of inertia of the beam in inches^4

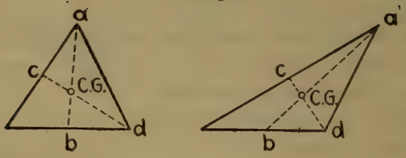
e = distance in inches from the neutral axis to the outer fiber

TABLE 66. CENTERS OF GRAVITY OF ORDINARY PLANE FIGURES



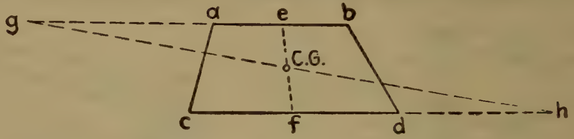
Squares, rectangles, parallelograms. Center of gravity is at the intersection of the diagonals or midway between the bases on a line drawn between the centers of those bases.

Triangles



Center of gravity is at the intersection of the medial lines *a b* and *c d;* a medial line is a line drawn from any apex to the middle of the opposite side The distance *b* (*C. G.*) = $\frac{1}{3}$ *a b;* that is, the center of gravity is on the medial line $\frac{1}{3}$ of the distance from the base to the apex.

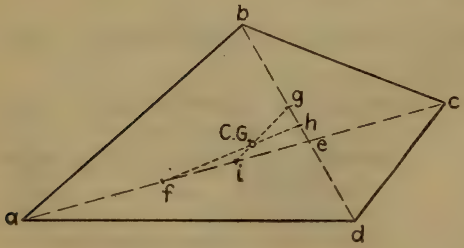
Trapezoid



Graphic Method. Prolong *b a* to *g*, making *a g* = *c d*. Prolong *c d* to *h*, making *d h* = *a b*. Connect *g h*. Bisect *a b* at *e*. Bisect *c d* at *f*. Connect *e f:* the intersection of *g h* and *e f* is the center of gravity.

The distance $f\ (C.G.) = \frac{ef}{3} \times \frac{2\,ab + cd}{ab + cd}$

Any Quadrilateral



Graphic Method. Draw the diagonals *a c* and *b d* intersecting at *e*.

Lay off *a f* = *e c*

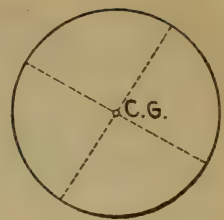
Lay off *b g* = *e d*

Bisect *e g* at *h*; bisect *e f* at *i*.

The intersection of *f h* and *g i* is the center of gravity of the figure.

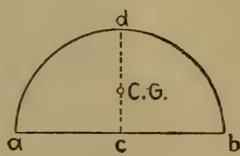
Circles

Center of gravity at the center



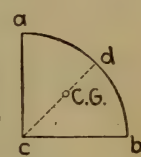
Semicircle

The center of gravity lies on the radius perpendicular to the diameter. The distance c ($C.G.$) = radius × 0.4244



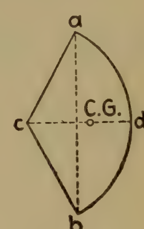
Quadrant

The center of gravity lies on the radius which bisects the ∠ $a\,c\,b$. The distance c ($C.G.$) = radius × 0.6002



Sector

The center of gravity lies on the radius bisecting the ∠ $a\,c\,b$. The distance c ($C.G.$) ≡ $\frac{2}{3}$ radius × $\frac{\text{chord } a\,b}{\text{arc } a\,d\,b} = \frac{\text{radius}^2 \times \text{chord}}{3 \times \text{area}}$



Segment

The center of gravity lies on the perpendicular erected at the center of the chord ab. The distance c ($C.G.$) = $\frac{\overline{\text{chord } ab}^3}{12 \times \text{area of segment}}$

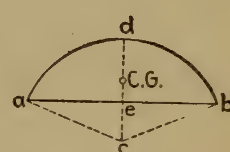
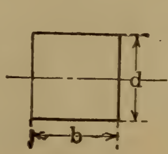
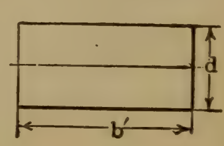


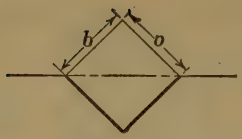
Table 67. Moments of Inertia of Simple Sections

I = Moment of Inertia

$$I = \frac{bd^3}{12}$$

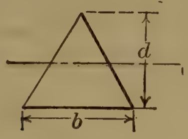






Square

$$I = \frac{b^4}{12}$$

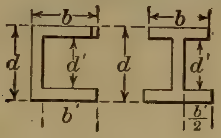


Triangles

$$I = \frac{bd^3}{36}$$

Circles

$$I = 0.7854\,R^4$$



$$I = \frac{bd^3 - b'd'^3}{12}$$

APPENDIX A

TRAFFIC RULES AND REGULATIONS, STATE OF OHIO

FOREWORD

Inasmuch as Section 249 of the Cass Law, (G. C. 7246) directing the state highway commissioner to prepare and publish a set of traffic rules and regulations, is for the protection of life and limb, it is undoubtedly the most important section of the road laws of Ohio.

After much thought and investigation of rules and regulations governing traffic conditions in a number of states, we submit the following in as condensed form as explicitness will permit, having selected, as we believe, the better parts of such laws and regulations governing the traffic of other states and municipalities, and putting them into a code of rules and regulations that will fit, as nearly as may be, all conditions and localities requiring a code of regulations, which will at the same time govern traffic on all the highways of Ohio.

A cursory examination of these rules may lead many to the conclusion that unreasonable restrictions have been imposed, but we believe a thoughtful study of each section will reveal an effort on the part of the State Highway Department to furnish the public with a code of traffic regulations, permitting of the greatest amount of freedom consistent with *safety first*.

The original draft of the following regulations was submitted to Mr. W. A. Alsdorf, Secretary of the Ohio Good Roads Federation, Mr. Harry Gordon of Cincinnati, and Mr. Fred Caley of Cleveland, who carefully studied the entire code, section by section, and suggested many valuable and important changes.

We now put forth the result of our efforts with the belief that if the prescribed rules and regulations are followed, many embarrassing situations and distressing accidents may be averted.

Clinton Cowen,
State Highway Commissioner.

ARTICLE I — DEFINITIONS

Sec. 1 — The term "vehicle" shall apply to a horse being rode or led, and to any conveyance except a baby carriage or street car.

Sec. 2 — The term "street car" shall apply to any conveyance confined to tracks.

Sec. 3 — The term "driver" shall apply to the rider, driver, or leader of a horse, a person who pushes, draws, propels, operates, or who is in charge of a vehicle.

Sec. 4 — The term "road" shall apply to that part of a street or public highway intended for vehicles.

Sec. 5. — The term "curb" shall apply to the boundary line of a road.

Sec. 6 — The term "sidewalk" shall apply to a path or walk intended for pedestrians.

Sec. 7 — The term "horse" shall apply to any draft animal or beast of burden.

Sec. 8 — The term, "motor vehicle" shall apply to all vehicles propelled by power other than muscular, except a street car, traction engine, road roller, and police, fire or ambulance vehicles.

ARTICLE II — RESPECTIVE RIGHTS AND DUTIES OF DRIVERS AND PEDESTRIANS

Sec. 1 — Roads are primarily intended for vehicles, but pedestrians have the right to cross them in safety, and drivers shall exercise all possible care not to endanger them.

Sec. 2 — Pedestrians should observe the following precautions;

1st. Avoid interference with vehicular traffic, and to this end not step onto the road without first looking to see what is approaching:

2nd. Cross the road at right angles — at regular crossings where such exist, — and where a traffic officer is stationed, wait for his signal.

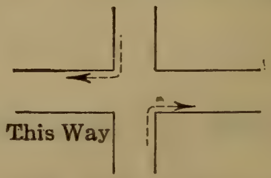
Sec. 3 — Pedestrians will aid in expediting traffic on side-walks by keeping to the right, and when stopping for any purpose by doing so on one side and out of the way of a crossing or driveway.

ARTICLE III — PASSING TURNING, STOPPING, STANDING AND STARTING

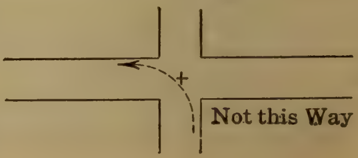
Sec. 1 — A vehicle meeting another shall keep to the right, so as to leave half the road free for the coming vehicle. (6310 G. C.)

Sec. 2 — A vehicle overtaking another shall pass to the left, the front vehicle giving half the road to the rear vehicle. (6310 G. C.)

Sec. 3 — A vehicle turning into a road to the right shall turn the corner as near the right hand curb as practicable.

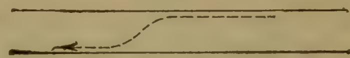


Sec. 4 — A vehicle turning into a road to the left shall pass around the point of intersection of the center lines of the two roads.



SEC. 5 — A vehicle crossing from one side to the other of a road shall head in the same direction as the traffic on that side of the road.

This Way



Not this Way

SEC. 6 — On heavy traffic roads, slow moving vehicles shall keep close to the right hand curb so as to leave the center of the road clear for overtaking traffic — *the slower the speed the nearer the curb.*

SEC. 7 — A vehicle in passing around a circle shall keep to the right from entrance to exit.

SEC. 8 — A vehicle on a road divided longitudinally by a parkway, walk, rope or other obstruction, shall keep to the right of such division.

SEC. 9 — A vehicle shall not back to make a turn if by so doing it obstructs traffic, but shall go forward to a point where a turn can be made without backing.

SEC. 10 — A vehicle shall not follow another too closely for safety.

SEC. 11 — No vehicle shall stop in the road in such a position as to prevent the free passage of other vehicles in both directions at the same time.

SEC. 12 — A vehicle shall not pass a street car which has stopped to receive or discharge passengers at a less distance than ten feet, nor at a greater speed than six miles per hour. A vehicle shall come to a stop if necessary to prevent interference or injury to such passengers.

SEC. 13 — No horse or vehicle shall be driven, propelled or allowed to stand, on any side-walk except for purposes of crossing the same when necessary, and then only the shortest way from the road to the abutting premises.

SEC. 14 — No vehicle shall stop in such a way as to interfere with the passage of pedestrians at regular crossings, or within 10 feet of a fire plug.

SEC. 15 — No street car shall stop or stand within the intersection of any road.

ARTICLE IV — LOADS, LOADING, WIDTH OF TIRE, TRAILERS, ETC.

SEC. 1 — No traction engine or other vehicle whose wheels have tires equipped with lugs, spikes, chains or other projections seriously destructive to the surface, shall be driven over the road. (13421–12 G. C.)

SEC. 2 — No vehicle or load, the total width of which is greater than twelve feet, shall be operated or drawn over a road unless said greater width will leave one-half the road free for passing vehicles.

SEC. 3 — No more than thirty-four hundred pounds including weight of vehicle, shall be transported over a gravel, macadam or stone road in a vehicle having a tire less than three inches in width. (7477 G. C.)

SEC. 4 — For vehicles having tires three inches and over in width the load on any wheel per lineal inch of width of tire on any road shall not exceed six hundred pounds; and during such times as the road surface is soft, because of thawing or because of excessive rains, the load per lineal inch of width of tire on any wheel shall not exceed three hundred pounds on gravel or macadam roads.

SEC. 5 — Trailers used in hauling over the road shall be so connected that the wheels of no two will follow in the same tracks.

SEC. 6 — No vehicle carrying a load in excess of fifteen tons, including the weight of the vehicle, shall be moved over any road except under the written permission of the State Highway Commissioner.

ARTICLE V — SPEEDS

SEC. 1 — No motor vehicle shall operate on a road at a greater speed than:

8 miles per hour in the business or closely built up portions of a municipality;

15 miles per hour in other portions of a municipality;

20 miles per hour outside of municipalities. (12604 G. C.)

SEC. 2 — No vehicle shall operate on a road at a speed greater than is reasonable or proper or so as to endanger the property, life or limb of any person. (12603 G. C.)

SEC. 3 — No motor or other power vehicle carrying a weight in excess of four tons including a vehicle shall be operated upon any road at a speed greater than 15 miles per hour; and no such vehicle carrying a weight in excess of eight tons including the vehicle shall be operated at a speed greater than 6 miles per hour when such vehicle is equipped with iron or steel tires, nor greater than 12 miles per hour when the vehicle is equipped with tires of rubber or other similar substance.

SEC. 4 — No vehicle shall cross a road or make any turn at a dangerous speed.

SEC. 5 — Where "Danger" and "Go Slow" signs appear, the speed of any vehicles shall not exceed twelve miles per hour.

SEC. 6 — Trucks and heavy wagons shall not be driven recklessly so as to endanger the public.

SEC. 7 — No vehicle shall emerge from an alley, stable, garage or any private drive or entrance faster than a walk or six miles per hour.

SEC. 8 — A vehicle upon approaching a cross road shall slow down sufficiently to prevent any danger from meeting other vehicles on the cross road.

SEC. 9 — No person shall race any horse or motor vehicle on a road whether the running, racing or trotting be for trial or speed or for the purpose of passing another horse or vehicle.

SEC. 10 — A motor vehicle, road roller or traction engine shall slow down when approaching a horse, if the horse appears to be frightened, and if the driver of the horse shall signal the driver of the vehicle the latter shall be brought to a stop, and if the circumstances require it, the engine shall be stopped, provided such signal

be given in good faith and under circumstances of necessity. Such vehicle shall remain stationary so long as may be reasonable to allow such horse to pass. (12605 G. C.)

SEC. 11 — In case of injury or damage to person or property, due to the operation of vehicle, the operator or driver of said vehicle shall stop, and, upon request of the person injured or any one present, give his name and address and that of the owner of the vehicle. (12606 G. C.)

ARTICLE VI — SIGNALS, HORNS, SIGNS AND NOISES

SEC. 1 — All motor vehicles and bicycles shall be equipped with a suitable bell or horn for signalling. (12614 G. C.)

SEC. 2 — When a vehicle is slowing up or stopping, the driver shall give a timely signal to those in the rear, by raising the arm or whip vertically (preferably) or horizontally or by some other unmistakable manner.

SEC. 3 — When about to turn either from a standstill or while in motion, the driver of a vehicle shall give timely signal by hand or whip or in some other unmistakable manner, to indicate the direction of the turn. *This is especially important when turning to the left.*

SEC. 4 — Before a vehicle is backed, the driver shall give timely warning.

SEC. 5 — Sound signals are prohibited except for necessary warning, and must be reserved for that purpose. Signals shall not be sounded by unauthorized persons on standing vehicles.

SEC. 6 — All signs, signals and orders of a traffic officer shall be promptly complied with.

SEC. 7 — Every driver of a motor vehicle shall give a timely warning when overtaking a person or vehicle on a road or when approaching a crossing or curve where the sight of approaching vehicles may be obscured.

SEC. 8 — No vehicle shall be so loaded as to cause an objectionable or unnecessary noise by parts of the load striking together or upon the vehicle.

SEC. 9 — The use between the hours of 8 P. M. and 6 A. M. of the muffler cut-out or the production of any other unnecessarily loud noise on any vehicle, is prohibited within 100 yards of any residence or within such distance as might seriously disturb the inhabitants of such residence.

SEC. 10 — No vehicle shall pass over any road which is closed against traffic to be repaired or constructed. A suitable sign or barricade shall be considered as sufficient evidence that such road is closed. (13421–9 G. C.)

ARTICLE VII — RIGHT OF WAY

SEC. 1 — Every driver of a vehicle approaching the intersection of a road where a traffic officer is not stationed, shall *grant the right of way at such intersection to any vehicle approaching from his right.*

SEC. 2 — A vehicle in front of a street car shall immediately turn out upon the signal of the operator of the car.

SEC. 3 — A vehicle shall not so occupy any road as to obstruct traffic.

SEC. 4 — When in the performance of duty, the following vehicles shall have the right of way: Police, Fire, Fire Patrol, Ambulance, U. S. Mail; also the militia.

SEC. 5 — During blockades and stoppages a clear space shall be kept open between all street cars at crossings.

SEC. 6 — Pedestrians about to get on, or just having been discharged from, a street car shall have the right of way and vehicles shall come to a stop when necessary to give such pedestrians the right of way.

ARTICLE VIII — LIGHTS

SEC. 1 — Motor vehicles shall display between 30 minutes after sunset and 30 minutes before sunrise, two white lights in front of sufficient power to be visible 200 feet away in the direction the vehicle is moving, and one red light visible in the opposite direction; also one rear white light which shall illuminate and make plainly visible the license number tag. Provided that motorcycles need have but one front light. (12614 G. C.)

SEC. 2 — During the same period given in Sec. 1, bicycles shall have a light of sufficient power to be seen 200 feet in the direction the bicycle is moving.

SEC. 3 — Bright lights on any vehicle or street car operated within the limits of the right of way of any road shall be dimmed or controlled while approaching and passing another vehicle so as to protect from the direct glare, the eyes of a driver 200 feet ahead and whose eyes are 5 feet above the road surface.

SEC. 4 — In order to avoid accidents and for the purpose of securing the greatest possible safeguard to human life, all drivers of horse drawn vehicles are urged and requested to display a light at night that can be seen both in front and in the rear.

ARTICLE IX — MISCELLANEOUS REGULATIONS

SEC. 1 — The unnecessary emission of dense smoke from motors is forbidden.

SEC. 2 — No horse or other domestic animal shall be allowed to run loose and unattended upon the road.

SEC. 3 — No vehicle shall be used or so loaded as to permit its load to be scattered over the road in such a way as to be objectionable to traffic or detrimental to the road. In no case shall ashes, garbage or other vegetable matter be scattered over the road surface.

SEC. 4 — No one shall ride on any vehicle without the consent of the driver.

SEC. 5 — No road shall be blocked or obstructed by any farm implements or other machinery or obstructions except when the road is legally closed for repair or construction. (13421–11 G. C.)

SEC. 6 — No person shall operate a motor vehicle while in a state of intoxication. (12626–1 G. C.)

SEC. 7 — Any special rules or regulations for any road or portion of a road which are conspicuously displayed at either end of such road or have been made known to the driver of a vehicle by a road official, shall be strictly observed by all drivers of vehicles over the road. (7246 G. C.)

SEC. 8 — Drivers of vehicles shall observe such care as is necessary to preserve the life of the road; — avoid following the tracks of a vehicle preceding them, and avoid driving in the ruts that may have started to form in the road surface.

SEC. 9 — Any person operating a vehicle or moving a load, or who is responsible for the operating of a vehicle or the moving of a load over a road in violation of any of the rules and regulations applying to such road, in addition to the fine imposed shall be responsible for all damage which said road may sustain as a result of such violation. (13421–17 G. C.)

While a good set of Traffic Rules and Regulations will be of great service to the public, yet in connection with any set of rules and regulations that may be in force, it will be necessary for drivers to exercise common sense and good judgment to avoid accidents and protect the roads. By a careful distribution of the traffic over a good road surface, roads may be made to last several times as long as they will last when all traffic concentrates in a single track. Every individual should remember that he helps build and maintain the roads regardless of the direct taxes he pays, and hence it is to his interest that the roads be used in such a way as to preserve them and render the greatest service to the general public.

APPENDIX

SEC. 6290 (G. C.) [**"Motor vehicle" defined.**] The term "motor vehicle," as used in this chapter and in the penal laws, except where otherwise provided, shall be deemed to include all vehicles propelled by power other than muscular power, except road rollers, traction engines, police patrol wagons, police automobiles, public ambulances, vehicles run upon rails or tracks, fire engines, fire trucks or other vehicles or apparatus belonging to any police department, municipal fire department, volunteer fire company or salvage company, organized under the laws of Ohio, or used by such police department, volunteer fire company, or salvage company, in the discharge of its functions or in transporting its officers, members, employes, men or articles necessary and proper for the proper discharge of such functions, to or from a fire or in response to any alarm of fire or to any other alarm or call to which it may respond. (100 v. 72; Am. 103 v. 763; 106 v. 139).

SEC. 6310 (G. C.) [**Meeting vehicle on highway.**] A person driving a carriage or vehicle on a public turnpike, road or highway, on meeting a carriage or vehicle, shall keep to the right so as to leave half of the road free for the coming vehicle.

A person riding on horseback or on a bicycle, tricycle, or tandem bicycle, or driving a locomobile, automobile, or any motor vehicle operated by its own power, on meeting a carriage or vehicle drawn by horses or oxen, shall keep to the right so as to leave one-half of the road free for the use of the vehicle drawn by horses, mules or oxen.

A person driving a carriage, vehicle, automobile, or any kind of vehicle, who desires to pass a vehicle going in the same direction on any public road or highway shall give an alarm or demand to the person or persons driving the vehicle in front and going in the same direction, of such desire, and the person so driving the front vehicle shall immediately give the half of the road to the rear vehicle, by turning to the right, so that the rear vehicle can pass to the left of the front vehicle.

[**Definition; penalty.**] The term vehicle herein shall apply to any vehicle propelled by its own power or drawn by horses or oxen. Any person or persons driving any vehicle, horse-drawn or otherwise, on any public road, who shall fail, in meeting or passing, to give the required road as herein stated, shall be subject to a fine in a court having jurisdiction thereof, in any sum not less than one dollar, nor more than ten dollars, and costs of prosecution. (R. S. Sec. 3490. Am. 103 v. 556).

Sec. 7246 (G. C.) [**Publication of traffic rules and regulations; special rules; enforcement.**] The state highway commissioner within sixty days after the taking effect of this act, shall prepare and publish a set of traffic rules and regulations governing the use of, and traffic on, all state roads. All rules and regulations that are to apply generally throughout the state, including those applicable to roads constructed of the various kinds of road material, shall become effective thirty days after publication. Special rules and regulations or orders, applying only to specified sections of state roads, shall become effective as soon as posted at each end, and at all road crossings on such specified section. For the purpose of carrying into effect the provisions of this section, it shall be the duty of the state highway commissioner, the county commissioners, the county highway superintendent, the township highway superintendent, township trustees, and all patrolmen or deputies employed on any highways within the state, to prosecute any violation of this section. It shall be unlawful for any person or persons, firm or corporation to enter upon, or travel over said state roads, except in accordance with the traffic rules and regulations promulgated by the state highway commissioner.

Sec. 7477 (G. C.) [**Weight of load and tire width prescribed.**] No person, firm or corporation, in a county having macadamized, graveled or stone roads shall transport over such roads, in a vehicle having a tire of less than three inches in width, a burden, including weight of vehicle, of more than thirty-four hundred pounds.

[**Board of directors and duties; penalty.**] The county commissioners shall constitute a board of directors for their respective counties, with power to prescribe the increased gross weight in excess of thirty-four hundred pounds that may be carried, including weight

of vehicles, in vehicles having a width of tire three inches or upwards, and cause such regulations to be recorded in their journal. Any person violating this section or any regulation duly prescribed by the board of county commissioners, made in pursuance thereof, shall be fined not less than five dollars nor more than fifty dollars.

[**Enforcement of traffic regulations.**] The township trustees of any township and the county commissioners of any county, shall cause to be prosecuted all persons violating this section or any regulations prescribed by the board of county commissioners made in pursuance of the authority conferred in this section. The county commissioners within their respective counties, may appoint a suitable person or persons to enforce such section and regulations. The person or persons so appointed shall receive for each conviction by them secured under this section, such portion of the fine or penalty as the commissioners deem just and proper.

SEC. 7478 (G. C.) [**Publication of traffic rules in counties.**] The state highway commissioner shall furnish the county highway superintendent with a copy of the rules and regulations promulgated by said state highway commissioner, and applicable to his county. The county highway superintendent shall cause the rules and regulations so furnished to him by said highway commissioner to be published, at least once each week, for two successive weeks, in a newspaper published and of general circulation in said county, if there be any such paper published in said county, but if there be no newspaper published in said county then in a newspaper having general circulation in said county. When such regulations are published in the manner aforesaid, it shall be deemed a sufficient publication under the provision of this act.

SEC. 12603 (G. C.) [**Operating motor vehicle unreasonably and improperly; penalty.**] Whoever operates a motor vehicle or motorcycle on the public roads or highways at a speed greater than is reasonable or proper, having regard for width, traffic, use and the general and usual rules of such road or highway, or so as to endanger the property, life or limb of any person, shall be fined not more than twenty-five dollars, and for a second offense shall be fined not less than twenty-five dollars nor more than fifty dollars. (99 v. 541, 543, Secs. 14, 25. Am. 103 v. 161).

SEC. 12604 (G. C.) [**Violation of speed limit.**] Whoever operates a motorcycle or motor vehicle at a greater speed than eight miles an hour in the business and closely built-up portions of a municipality or more than fifteen miles an hour in other portions thereof or more than twenty miles an hour outside of a municipality, shall be fined not more than twenty-five dollars, and for a second offense shall be fined not less than twenty-five dollars nor more than fifty dollars. (99 v. 541, 543, Sec. 15, 25).

SEC. 12605 (G. C.) [**Failure to stop motor vehicle when signalled.**] Whoever, operating a motor vehicle, fails to slow down and stop it when signalled so to do upon meeting or overtaking a horsedrawn vehicle or person on horseback and to remain stationary until such vehicle or person has passed, provided such signal to stop is given in good faith, under circumstances of necessity, and only

as often and for such length of time as required for such vehicles or person to pass, whether approaching from the front or rear, shall be fined not more than twenty-five dollars, and for a second offense shall be fined not less than twenty-five dollars nor more than fifty dollars. (99 v. 541, 543. Secs. 16, 25).

SEC. 12606 (G. C.) [**Failure to stop motor vehicle in case of accident.**] Whoever, operating a motor vehicle on a public road or highway, in case of an accident to a person or property thereon due to the operation of such motor vehicle, fails to stop upon the request of the person injured or a person present, give his name and address, and, if not the owner thereof, the name and address of such owner, shall be fined not more than twenty-five dollars, and for a second offense shall be fined not less than twenty-five dollars nor more than fifty dollars. (90 v. 541, 543, Secs. 16, 25).

SEC. 12607 (G. C.) [**Third or subsequent offense.**] For a third or subsequent offense, a person convicted of a violation of any provision of the next four preceding sections, shall be fined not less than fifty dollars nor more than one hundred dollars or imprisoned not more than thirty days, but if such subsequent offense occurred within one year after any former offense, he shall be imprisoned not less than ten days nor more than thirty days. (99 v. 543, Sec. 25.)

SEC. 12614 (G. C.) [**Penalty for failing to provide motor vehicle with bell, brakes, and lights.**] Whoever operates or drives a motor vehicle upon the public roads and highways without providing it with sufficient brakes to control it at all times and a suitable and adequate bell or other device for signalling, or fails during the period from thirty minutes after sunset to thirty minutes before sunrise to display a red light on the rear thereof and three white lights, two on the front and one on the rear thereof, the rays of which rear white light shall shine upon and illuminate each and every part of the distinctive number borne upon such motor vehicle, the light of which front lamps to be visible at least two hundred feet in the direction in which such motor vehicle is proceeding, shall be fined not more than twenty-five dollars. Provided, that motor vehicles of the type commonly called motor cycles shall display one white light in front to be visible at least two hundred feet in the direction in which such motor vehicle is proceeding, and one rear combination red and white light, showing red in the direction from which such motor vehicle is proceeding, and such rear light to be so placed that it will reflect its white light upon and fully and clearly illuminate the distinctive license identification mark of such motor vehicle. (99 v. 540, 543, Secs. 12, 24. Am. 103 v. 766).

SEC. 12628–1 (G. C.) [**Intoxicated person operating motor vehicle upon public highway or street, unlawful.**] That it shall be a misdemeanor for any person to operate a motor cycle or motor vehicle of any kind upon any public highway or street while in a state of intoxication, and upon conviction he shall be subject to punishment by a fine not less than twenty-five dollars, nor more than one hundred dollars, or imprisonment in the county jail for not more than six months, or both. (99 v. 544, Sec. 32. Am. 103 v. 133).

SEC. 13421–9 (G. C.) [**Driving over closed highway; penalty.**]

Whoever drives over, upon, along or across a public highway, or any part thereof, which has been closed, while in the process of construction, reconstruction or repair by order of the state highway commissioner, county highway superintendent, county commissioners, township trustees or other official or employe having authority to close such highway, shall be fined not more than fifty dollars, nor less than five dollars.

SEC. 13421-11 (G. C.) [**Placing obstruction in highway; penalty.**] Whoever unlawfully places any obstruction in, or upon a public highway, shall be fined not more than fifty dollars, nor less than five dollars.

SEC. 13421-12 (G. C.) [**Driving traction engine with destructive tires; penalty.**] Whoever drives over the improved highways of the state, or any political subdivision thereof, a traction engine with tires of wheels equipped with lugs, spikes, chains or other projections seriously destructive to such highways, or by any other means damages such highways, shall be fined for each offence not less than ten dollars nor more than two hundred dollars.

SEC. 13421-14 (G. C.) [**Digging, excavating, piling earth or building fence on highways; penalty.**] Whoever digs up, removes, excavates or places any earth or mud upon any portion of any public highway or builds a fence upon the same without legal authority or permission so to do, shall be fined not more than two hundred dollars nor less than ten dollars. Each day that such person continues to dig up, remove or excavate any portion of the public highway shall constitute a separate offence.

SEC. 13421-16 (G. C.) [**Placing nails, tacks, glass, etc., upon highway; penalty.**] Whoever places upon any part of a public highway, lane, road, street or alley, any tacks, bottles, wire, glass, nails or other articles, except such substances as may be placed there by proper authorities for the repair or construction thereof, which may damage or injure any person, vehicle or animal traveling along or upon said public highway, shall be fined not more than two hundred dollars or imprisoned not more than six months or both.

SEC. 13421-17 (G. C.) [**Violation of traffic rules; penalty.**] Whoever enters upon, or travels over any portion of the highways, within the state, in violation of the traffic rules and regulations duly prescribed by law, or the state highway commissioner, or the county highway superintendent of any county, shall be fined not more than one hundred dollars, nor less than five dollars, and in addition thereto, such person shall be liable for all damage done to such highway.

State of New York
Highway Commission

AMENDED RULES AND REGULATIONS FOR STATE AND COUNTY HIGHWAYS

Adopted by the Commissioner of Highways of the State of New York

Sec. 1. No traction engine, road engine, hauling engine, trailer, steam roller, automobile truck, motor or other power vehicle shall be operated upon or over State or County Highways of this State, the face of the wheels of which are fitted with flanges, ribs, clamps, cleats, lugs or spikes. This regulation applies to all rings or flanges upon guiding or steering wheels on any such vehicle. In case of traction engines, road engines or hauling engines which are equipped or provided with flanges, ribs, clamps, cleats, rings or lugs, such vehicles shall be permitted to pass over such highways provided that cleats are fastened upon all the wheels of such vehicles, not less than 2½ inches wide and not more than 1½ inches high, and so placed that not less than two cleats of each wheel shall touch the ground at all times, and the weight shall be the same on all parts of said cleats.

The foregoing regulations relating to flanges, ribs, clamps, cleats, rings or lugs shall not apply to traction engines used solely for agricultural purposes, but the following requirements shall apply to such traction engines:

The guide band on the front wheels shall not be less than two inches in width, but no flanges, ribs, clamps, cleats, rings or lugs shall be required upon the front wheels. The full set of cleats upon the rear wheels of the original design as furnished with the engines must be used, and no rivet heads or bolt heads shall project, and the use of such traction engines for agricultural purposes shall not permit the use for hauling purposes, excepting the hauling of threshing and other agricultural equipment necessary for threshing and agricultural purposes.

This provision shall in no case relieve the owner of any traction engines from liability for damage to roads from defective wheels.

The use also of ice picks or mud lugs shall be strictly prohibited on State and County Highways.

Sec. 2. No traction engine, trailer, steam roller, automobile truck, motor or other power vehicle shall be operated upon or over the State or County Highways of this State, nor shall any object be moved over or upon any such highways upon wheels, rollers or otherwise, in excess of a total weight of fourteen tons, including the vehicle, object or contrivance and load, without first obtaining the permission of the State Commission of Highways as hereinafter provided. No weight in excess of nine tons shall be carried on any one axle of any such vehicle.

Sec. 3. The tire of each wheel of a traction engine, road engine, hauling engine, trailer, steam roller, automobile truck, motor or other power vehicle (except traction engines, road engines, and hauling engines) shall be smooth, and the weight of such vehicle, including

load, shall not exceed 800 lbs. upon any inch in width of the tire, wheel, roller or other object, and any weight in excess of 800 lbs. upon an inch of tire is pibrohited unless permission is obtained from the State Commission of Highways as hereinafter provided.

SEC. 4. No motor or other power vehicle shall be operated upon any State or County Highway of a greater width than ninety inches, except traction engines which may have a width of one hundred ten inches.

SEC. 5. No traction engine, road engine, hauling engine, trailer, steam roller, automobile truck, motor, or other power vehicle, carrying a weight in excess of four tons, including the vehicle, shall be operated upon any State or County Highway of this State at a speed greater than fifteen miles an hour; and no such vehicle carrying a weight in excess of six tons, including the vehicle, shall be operated upon any such highway at a speed greater than six miles an hour when such vehicle is equipped with iron or steel tires, nor greater than twelve miles an hour when the vehicle is equipped with tires of hard rubber or other similar substance.

SEC. 6. The State Commission of Highways of the State of New York, upon proper application in writing, may grant permission for the moving of heavy vehicles, loads, objects, or structures in excess of a total weight of fourteen tons over its State and County Highways upon proper application in writing being made therefor, and under such restrictions as said Commission may prescribe.

SEC. 7. The owner, driver, operator or mover of any vehicle over any State or County Highway shall be responsible for all damage which said highway may sustain as a result of a violation of any of the provisions of the foregoing Rules and Regulations, and the amount thereof may be recovered in an action of tort by the State Commission of Highways or by any County Superintendent of Highways of any county or by any Town Superintendent of Highways in any town in which said violation occurs.

SEC. 8. These amended regulations to take effect February 24, 1914.

"Section 24 of Chapter 25 of the Consolidated Laws, entitled 'The Highway Law,' provides that any disobedience of any of the foregoing rules and regulations shall be punishable by a fine of not less than $10, and not more than $100, to be prosecuted by the Town, County or District Superintendent, and paid to the County Treasurer to the credit of the fund for the maintenance of such highways in the town where such fine is collected."

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